CLIMATIC CONTROL

BY

L. C. W. BONACINA

FELLOW OF THE ROYAL METEOROLOGICAL SOCIETY

360

ILLUSTRATED WITH SKETCH-MAPS, DIAGRAMS, AND WEATHER CHARTS

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CLIMATIC CONTROL

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SCOTTISH MOUNTAINS AND STORM-WREATHS.

The wild, desolate, but romantic scenery of the Scottish Highlands everywhere reflects a cold, wet, and treacherous climate.

Hast thou perceived the breadth of the earth?

—JOB xxxviii. 18.

PREFACE

At the end of 1909 I was asked to contribute to this series a small textbook on the subject of climatic control for use in schools. To deal adequately with so extensive a subject in a small book was, of course, impossible, and I found it necessary to select a certain number of subjects illustrating climatic effects, with the result that the book should be regarded, not so much as a compendium of information, as a guide to help the student to observe and think for himself, since climatic effects are discernible everywhere on the face of the globe and in the life upon it. The first chapter on the principles of climatology should be regarded as introductory to the following six chapters on the subject of climatic control.

The special prominence given throughout to the study of the British climate and its effects is due to the book being intended primarily for British scholars, who should carefully observe the climatic and general geographic features of their own country; and this, moreover, is in accordance with my own intimate personal knowledge of the climate of Britain.

For numerous illustrations of climatic influence in foreign lands, I am specially indebted to the standard and only work on the subject, namely, R. de C. Ward's "Climate considered especially in Relation to Man" (U.S.A.), and also to the Hon. Ralph Abercromby's

"Seas and Skies in Many Latitudes." The concluding chapter of the book, on Meteorology, is intended for more advanced students. In order not to unduly extend the size of this chapter I have omitted many matters which will be found discussed in textbooks on meteorology, such as electrical effects like lightning, or the aurora and optical manifestations like the rainbow.

I would urge teachers desirous of further pursuing meteorology as a class subject to teach the subject both from the standpoint of Natural Philosophy and of Natural History, for it is only by endeavouring to understand something of the physical causes underlying weather phenomena, as well as closely observing and recording the phenomena themselves, that the full grandeur of the science of the atmosphere is brought out. My best thanks are due to Dr. H. R. Mill, Director of the British Rainfall Organisation, for his friendly help in revising the entire proof-sheets; to Mr. Edward Heawood, M.A., Librarian to the Royal Geographical Society, for revising the proofs of Chapter VII.; and to Professor L. W. Lyde for valuable suggestions as editor of the work. To Dr. H. R. Mill I am also indebted for the loan of the rainfall map of the British Islands on p. 61.

The temperature map of the world, on p. 33, has been adapted to the requirements of the book from Buchan's original isothermal charts.

The reproduction of five Daily Weather Charts of the Meteorological Office at the end of the volume is by permission of the Controller of H.M. Stationery Office.

L. C. W. BONACINA.

LONDON,
July 15, 1911.

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CLIMATIC CONTROL

CHAPTER I

GENERAL PRINCIPLES OF CLIMATOLOGY

I. Etymology of the Word "Climate."—The word *climate* has no obvious connection with the weather, *i.e.*, our atmospheric environment, and might be taken literally to mean, indifferently, "zone," "belt," or "region," being derived from the Greek word *klimata* —"slopes" or "regions." The ancient Greeks may have had in view the different atmospheric conditions associated with the different exposures of mountain slopes as well as the supposed slope of the earth towards the poles. By the great authors of English literature *climate* is often used in the sense of general physical environment—to include soil, scenery, etc., as well as atmosphere; but the modern usage of the word is in relation solely to atmospheric or aerial conditions, and in the science of meteorology, which treats of atmospheric or weather phenomena, it is so restricted as to admit of a more or less concise definition.

II. Definition of Climate.—The term *climate* is commonly used by modern meteorologists to denote the average state of the weather over any particular area of the earth's surface. Thus, when we speak of the climate

of the British Islands as being damp and cloudy, we mean that damp and cloudy weather are more prevalent, or occur on more days during the year, than dry and sunny weather. This, however, is not a complete definition, and it is more satisfactory to include in our idea of climate the less common or rarer forms of weather as well as the more common, and to consider how often each specific kind of weather, common or rare, is liable to occur in a particular region.

Formulated thus on broader notions, the term "climate" may be considered as furnishing us with a bird's-eye view, as it were, of the frequency with which different kinds of weather—hot, cold, sunny, cloudy, damp, dry, windy, calm, etc.—occur in a given country in the course of a year or season. It is quite correct, for example, to describe the British winter climate as wet and stormy, because wet and stormy weather is more prevalent in our sea-girt land than dry and frosty weather; but dry and frosty weather is liable to occur at intervals, and a true picture of the climate must show us how often periods of severe frost are liable to interrupt the more usual wet and windy conditions of the atmosphere. Again, out of 100 days in the year, taken at random, there will be, roughly, in England 30 days overcast or nearly overcast, 60 days with a sufficient proportion of cloud in the sky to be called cloudy, and only 10 days cloudless or nearly cloudless. The climate of England may, therefore, be justly called very cloudy; but, in forming this estimate, it must be borne in mind that the 10 clear, cloudless days are certain to occur, and are as much part and parcel of the climate of England as the 90 days with varying amounts of cloud. Briefly, then: *Climate denotes the frequency with which different states of weather*

occur over a given area in the course of a year or series of years.

III. Factors of Climate.—One of the first facts to be learnt in elementary geography is this: that the polar regions of the earth are cold, that the Equatorial region is hot, and that the intermediate zones, or regions, are intermediate in average temperature, being the so-called Temperate Zones. In other words, one learns that temperature depends upon what is called latitude. It soon becomes apparent, however, that latitude, although the most important, is not the only factor concerned in regulating the temperature and general climate of a locality, but that height above sea-level, distance from the sea, and other factors play an important rôle.

The mighty chain of mountains in South America, for instance, known as the Andes is situated largely within the tropical, or hot zone of the earth, yet its lofty peaks are so cold as to be perpetually snow-clad, and have an entirely different climate from the hot plains stretching away from the base of the mountains. Similarly, England lies in the same latitude as portions of Russia and Canada, but possesses quite a different kind of climate—*marine* or *insular;* whereas the climates of Russia and Canada are known as *continental,* with a greater range of temperature between summer and winter and other characteristic differences. Temperature, though perhaps the most striking and important, is not the only condition of the atmosphere which constitutes the basis of what we call climate; and, since climate is to be looked upon as average weather, the former may be regarded as made up of a number of weather elements, such as temperature, humidity, rainfall, sunshine, wind, etc. These weather

elements, when considered in regard to their relative frequency of occurrence in a locality, become *elements of climate;* and, before we analyse climate as the product of certain definite factors or causes, such as latitude, altitude, distance from sea, etc., we must have a clear idea of what these elements are.

The elements of climate are frequently called factors in textbooks upon the subject, but it is better to reserve the word "factor" for cause or maker of climate, and use the word "element" in the sense of a constituent or component part. The elements of climate, then, may be divided into meteorological or atmospheric elements, and astronomical or mathematical. The chief meteorological or atmospheric elements are: The *average temperature or "hotness" of the air*, the *humidity* or *dampness of the air*, the *amount and duration of rain, snow, sunshine, cloud*, and the *velocity and direction of wind.* The astronomical or mathematical elements of climate are not so obviously connected with what we commonly understand as *weather* as the meteorological elements, but have a fundamentally important bearing upon it. They are: (1) *The duration of sunlight—i.e., the length of the day;* (2) *the intensity of the sun's light and heat—i.e., the intensity of solar radiation.* These two climatic elements are called astronomical, because they depend upon the altitude of the sun above the horizon at noon, and mathematical because they have known constant values for a given latitude at a given season of the year, changing only with latitude and with the season of the year. The facts that (1) at the poles the day is six months long to correspond with the summer season, and the night six months long to correspond with the winter season, and that (2), as one approaches the Equator, the difference between the longest and shortest

day diminishes till, at the Equator itself, day and night are the same length—twelve hours—the whole year round, are of the utmost importance in the proper study of climate, and must never be lost sight of. Briefly, then—

Climate = Meteorological + Astronomical Elements.

Now that we have a clearer idea of the elements which compose climate, it is time to classify the different factors which go to produce the climatic variations met with in different parts of the world. The climate of any spot on the surface of the earth is the final result or product of the co-operation of the following factors:

1. *Latitude*, or distance from the Equator.
2. *Altitude*, or height above sea-level.
3. *Prevailing wind-direction.*
4. *Distance from the sea*, especially with reference to warm or cold ocean currents.
5. *Topographical features*: water, mountain and hill ranges, forests, deserts, cultivated land, towns, etc.; general character of surface.
6. *Geological formation and structure*: nature and character of rock and soil.

Since the above list of climatic factors embraces all known influences which modify climate and produce the variations in it found on different parts of the globe, it will be necessary to study each factor separately in order to understand how each operates.

IV. To begin with—(1) **Latitude.**—The reason why it gets hotter from the poles to the Equator is simply that at the Equator the sun shines more or less vertically over the earth during the midday hours, whereas it shines more and more obliquely the greater the distance

from the Equator. The explanation of this is twofold. The primary or chief explanation why a vertical or overhead sun is hotter than an oblique or slanting sun is a purely *geometrical* one, and may be illustrated very simply (Fig. 1).

Here AB and CD are straight lines drawn to represent sunbeams striking a portion of the earth's surface (supposed flat for simplicity) vertically; and EB and FG are straight lines drawn to represent beams of exactly the same width striking the surface obliquely at an angle of about 45 degrees. It will be

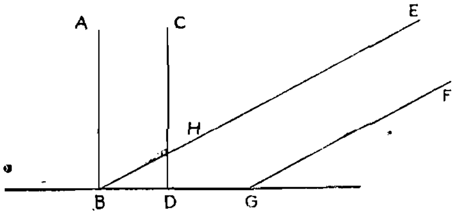


FIG. 1.

noticed that the line BD, taken to represent one side of a square area on which the vertical sunbeams fall, is shorter than the line BG, representing one side of a square on which the inclined beams fall; and this simply means that the same quantity of the sun's energy of light and heat which, when contained in the vertical or normal beams, is received by the square surface represented by the straight line BD, is, when contained in the oblique or inclined beams of the same width, spread over the larger square surface represented by the straight line BG.

Hence any spot in the smaller area BD receives more heat than a spot of equal size in the larger area BG. The difference, of course, increases with the

degree of inclination of the solar rays. This, then, is the chief reason why the sun's rays are more powerful, and the climatic conditions consequently warmer, in the Equatorial region than in higher latitudes, where they shine more obliquely.

But there is another, although much less important, reason why the vertical sun of the tropical zone is stronger than the oblique sun of the temperate regions; and this is a *physical* one, depending upon the fact that the sun's rays have to pass through a smaller thickness of the earth's atmosphere in the former case. The gaseous envelope, or atmosphere, which invests the globe, extending in appreciable density up to a height of some fifty miles above the surface, has the property of arresting and absorbing a considerable proportion of the light and heat which penetrates it from the sun; and it is obvious that, the greater the thickness of the atmosphere traversed, the greater will be the absorption of heat and light before the sun's rays reach the ground. Hence, on this account alone, the sun would shine more feebly in high latitudes than in low. It is just for this reason, also, that you can look at the sun with comparative comfort at the time of rising and setting, when he is on the horizon, but cannot do so for more than a second or so at midday, when he is high up in the sky, and transmitting his rays more directly through the atmosphere. This principle may be roughly illustrated in Fig. 2 above. If the shaded area be taken to represent the earth, and the outer semicircle the upper limit of the atmosphere (the thickness of the atmosphere being, of course, exaggerated), it will be seen that a ray of sunlight,

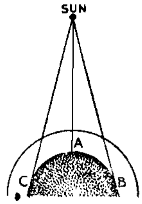


FIG. 2.

falling vertically on to the earth's surface at a spot near the equator A, has much less atmosphere to traverse than rays falling obliquely at spots near the poles B C.

Many of the other climatic elements besides temperature vary as we proceed from the Equatorial to the Polar regions. Thus, speaking generally, the rainfall is, with certain notable exceptions (such as the desert regions of the Sahara and Australia), greatest in the hottest parts of the globe and least in the coldest; and so also is the humidity or quantity of water-vapour present in the atmosphere. But these and other effects are themselves largely dependent upon the difference of temperature, and the consideration of them must be left for our chapter on Meteorology at the end of the volume.

V. (2) **Altitude.**—After latitude the most important condition which modifies the temperature and general climate of a locality is its *altitude*, *elevation*, or *height* above the level of the sea (or its depth below it, in cases where the land lies lower than the sea), the sea-level constituting the most convenient datum line for comparing heights.

Personal experience in scaling hills and uplands shows us that, the higher the land, the colder, in a general way, does the climate become. We find how late the spring is on the bleak hills, and how long the snow persists after it has disappeared from the lowland vales. High mountains, even at the Equator, are always regions of perpetual snow and ice; and thus we have the interesting fact that, in passing through a short *vertical* distance measured in some thousands of feet, we meet successively all the climatic zones to be found in the *horizontal* distance of some 6,000 miles between the Equator and the poles. A fine illustration of this is

afforded by the Ruwenzori and Kilimanjaro mountain groups of Equatorial Africa, which, containing peaks nearly 20,000 feet above the sea, rise deserts of perennial snow out of the hot, steamy plains with all the luxuriance of tropical vegetation at their base. In Scotland the snow-line, or limit of perpetual snow, *would* lie at about 5,000 feet, and the highest land in the country—namely, Ben Nevis (4,406)—therefore just fails to attain it. Fig. 3 shows how the average height

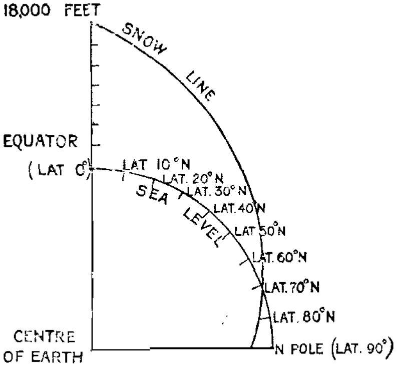


FIG. 3.

Showing descent of snow-line over half of the Northern Hemisphere, from 18,000 feet over the Equator to sea-level in latitude 70°. (Vertical scale above sea-level of course exaggerated.)

of the snow-line descends with increasing distance from the Equator. The great heat at the Equator sends the limit of everlasting snow and ice up to 18,000 feet, but at about latitude 70° N., a little within the Arctic Circle, the cold in some regions is already so great that the line cuts the surface at sea-level. The precise causes of the fall of temperature with increasing elevation are somewhat perplexing; but, before leaving this paragraph, we must try to obtain a general idea of

the chief of them. In the first place, the atmosphere keeps the earth warm somewhat in the same way that clothes and blankets keep your body warm—namely, by preventing the heat derived from the sun escaping back into space too quickly. Now, at great heights the atmosphere is very thin or rare, and cannot act as a warm blanket; and mountain-tops are cold, partly because the air is too thin to form a sufficient covering to keep in the heat which their surfaces receive from the sun, and partly because they stand isolated, as it were, in the cold high levels of the atmosphere where the air is not heated by the rays of the sun which pass through it (see chapter on Meteorology).

There is one great difference to be carefully observed between the change of climate due to increase of latitude and the change due to increase of altitude. Whereas with increase of latitude the sun's rays grow weaker, and thus allow the temperature of the earth and air to fall, with increase of altitude the rays become brighter and more powerful, because they have to traverse less of the atmosphere—the effect of which is not only to act as a blanket in preventing the heat already received from the sun escaping from the earth, but also to absorb a considerable portion of the direct rays of the sun, and thus act as a screen to the earth. On snowy mountain-tops the solar radiation is fiercely hot and bright owing to the thinness and purity of the atmosphere—the very same cause which renders it ineffective in warming the mountains up and keeping them free of snow. Lofty mountain peaks are of course slightly nearer the sun than the rest of the earth's surface, but the increase in the strength of the solar rays depending upon the ratio of a few miles to some ninety-two millions of miles is absolutely negligible. Other possible sources of the

cold on elevated land will be referred to in the chapter on Meteorology.

VI. (3) **Prevailing Wind-Direction.**—Whilst the velocity or strength of the wind is clearly part of the weather itself, and the average velocity enters into the composition of the general climatic conditions of a locality, the average direction from which the wind blows is distinctly a factor of climate, as defined in III., and a very important one, for upon it largely depend temperature, humidity, cloudiness and rainfall—in fact, the general character of the climate. In the British Islands the wind is very variable in direction, but the prevailing direction is between south and west; and this fact of the wind coming from warm latitudes and blowing over the warm Atlantic Ocean causes us to have a higher average temperature, with more rain and cloud, than our high northern latitude between the 50th and 60th parallels alone would allow. In spring, however, the wind shows a tendency to blow from the opposite quarter of the compass—that is, between north and east—and the consequence of this is that the bitter cold of the early year is protracted till very late into the season, sometimes almost till mid-summer, especially in the northern parts of Britain, where the backward character of the spring is one of the great disadvantages of the climate. The wind, then, is an importer of temperature—of cold from high latitudes and heat from low latitudes, together with clouds and moisture; and what an enormously important climatic factor it is may be judged from the fact that in England a sweep of strong, moist, south-westerly wind from the Atlantic in the depth of winter renders the formation of frost impossible, whilst a flow of air from some northerly direction often brings brief spells of almost Siberian

cold. Perhaps the chief effects of the climatic influence of wind-direction may be observed in the Trade-wind belts of the earth (see Chapter II., Deserts). The subject of wind generally must be deferred till we come to speak of *meteorology* in connection with the *general circulation of the atmosphere.*

VII. (4) **Distance from the Sea; Ocean Currents.**—If you compare different countries situated between approximately the same parallels of latitude, you will observe that those near the sea or surrounded by it—*e.g.*, Ireland—enjoy a milder or more equable climate than such as lie, like Poland, far from the sea in the interior of continents: they have warmer winters, cooler summers, and, of course, a moister condition of the atmosphere. Now, the sea serves to modify the temperature of islands and coast-lines in two ways. Firstly, since the *specific heat* of water is very high as compared with that of dry land, and since, under the influence of *tidal* and *wind currents* and the *vertical circulation* due to *changes of temperature* and *salinity*, the water of the sea is being constantly intermixed, the surface of the ocean cannot get nearly so hot by day or in summer, or so cold by night or in winter, as the surface of the land. Now, the temperature of the air is very largely controlled by that of the surface beneath it, whether that be land or water, and the consequence of this is that the air which small islands and coast-lines receive from the sea, carries with it the equable temperature of the sea surface. When strong winds blow, these equable conditions are carried right across the interior of larger islands, and in any case winds off the ocean convey them to a greater or less distance into inland regions, whether of islands or not. Secondly, the sea is constantly giving off vapour, with the result

that the air above it is kept very damp and the sky often cloudy; and this tempers the heat of the sun in summer and during the day-time, and checks the cooling by terrestrial radiation in winter and during the night. Hence, for a double reason, islands enjoy a less extreme climate than continental regions.

Where warm or cool *ocean currents* flow near a coast, they exert a very special climatic influence. Thus, the naturally hot climate of the coastlands of Peru is very materially cooled by the Antarctic drift current; the naturally cold climate of Labrador is rendered altogether inhospitable by the Arctic Labrador current; and the naturally cold climates of the British Isands and Norway are made much warmer by the Gulf Drift.

Marine currents, however, only act indirectly, and the Gulf Drift would have very little effect in warming British Isles and keeping the ports free from ice in winter without the medium of the prevailing *south-westerly winds.* For, the warm surface of the Atlantic Ocean prevents the south-westerly winds which blow over it, from being cooled down before they reach our high latitude, and hence enable them to bring warmth to our shores. In Germany strong south-west winds in winter cannot bring such a high temperature (50° or above) as in England, because they have been chilled by passing over a cold land surface.

VIII. (5) **Topographical Features.**—The general surface features of a locality—hills, lakes, rivers, woods, etc.—together with the manner of exposure to wind and sun, though exercising only a subordinate control over climate, nevertheless give rise to local differences of climate which greatly affect in one way or another the comfort of animals and plants. The chief influences under this heading may be here summarised:

(i.) Places in the Northern Hemisphere with a southerly exposure, and sheltered from the north by hills, enjoy a warmer climate than the average for their latitude. Thus Hastings, Ventnor, and Torquay, on the south coast of England, are mild, and suitable as winter resorts for invalids.

(ii.) Wooded or cultivated country has softer climatic conditions, with less extremes of temperature than open moorland.

(iii.) Mountains frequently give birth to violent hot or cold local winds in their neighbourhood, and cause the sequence of weather phenomena to be far more complicated than is observed in plains.

(iv.) River valleys and hollows among hills are liable to be cold and damp at night-time, and in winter are subject to severe frost, because the cold air tends to sink by its own weight down the hill-slopes and accumulate on the valley floor, thus intensifying the cold. On these occasions the hilltops, contrary to the general rule of decrease of temperature with height, are often much warmer than the valley bottoms.

(v.) Land that is well drained, by either natural or artificial means, is warmer and less liable to fogs than marshy ground, besides being much healthier.

(vi.) Large towns, owing to the numerous sources of artificial heat, have a mean temperature about a degree higher than the neighbouring open country.

IX. (6) **Geological Formation and Structure.**—The different kinds of rock and soil exert a direct influence upon climatic conditions in virtue of their different behaviour as regards their specific heat, their power to conduct heat, and also their permeability to water. Sandstone or loose sand, for instance, having a low specific heat, and being very permeable by rain-water,

heats up and cools down—and at the same time dries up —more quickly than most of the other common kinds of rock, with the result that sandy localities are characterised by a larger range of temperature between day and night and by greater dryness than others. The damp, flat clays of Essex and Middlesex, for example, which are very impervious to water, are apt to breed dense raw fogs in winter, whereas the dry, bracing, sandy heaths and hill-ridges of Surrey are comparatively free from fog. The great rainless regions of the earth are for the most part bare deserts of sand, subject to very great extremes of temperature. In the Sahara the sand at midday beneath the fierce rays of the tropical sun is sometimes hot enough to cook an egg, but after sundown it cools down under the clear, cloudless sky sufficiently to freeze water. The variations of temperature which rocks undergo as a result of direct radiation of heat to and from the earth's surface, are quickly imparted to the superincumbent air, and this is how the geological factor of climate comes into play.

X. Classification and Description of Climate.—The climate of any spot on the surface of the globe becomes the *net* result of the six *factors* above considered all operating together; and, such being the case, we must briefly see how the diverse climatic conditions met with on the earth may be classified and described. Some authors, like Supan, have attempted more or less elaborate systems of classification according to temperature and other conditions, but it may be said at once that, since different types of climate merge gradually into one another, the subject does not lend itself to detailed classification. The simple, broad classification into *torrid*, *temperate*, or *frigid* climates on the one hand,

and *continental* or *marine* climates on the other, forms probably the most satisfactory basis; beyond this a particular climate had best be *described* according to its own special features.

The Torrid, or Hot, Zone is conveniently regarded as bounded by the *Tropics of Cancer and Capricorn* at 23½° N. and S. of the *Equator* respectively. This zone may be subdivided into (1) Equatorial, to include the portion situated within about 10° N. and S. of the Equator, and (2) tropical, to include the portion from 10° N. and S. to the margins of the zone. The Equatorial region is hot and rainy, and the temperature changes very little; there are two rainy seasons in the year when the sun is vertical (see § XI. on Seasons), and the sky is generally more or less cloudy, and the air moist and oppressive. A typical example of an Equatorial climate is Borneo.

The tropical region is drier and clearer, with usually only one rainy season in the year. The range of temperature between day and night is very large, and during the dry season the heat is often more intense than in the Equatorial region.

Examples of tropical continental climates are India and the northern half of Australia, while an example of a tropical marine climate is given by the Fiji Islands.

The Temperate, or Intermediate, Zones, occupying the wide belt of the globe in either hemisphere between the tropics and the Arctic and Antarctic Circles, are roughly divisible by the 45th parallels of latitude N. and S. into *warm* temperate climates and *cool* temperate climates. The warm temperate countries have long, hot, and frequently parching summers and short winters; the cool temperate countries have long,

severe, or inclement winters and short summers. Examples:

Warm Temperate.		Cool Temperate.	
Continental (Extreme).	Marine or Insular (Equable).	Continental (Extreme).	Marine or Insular (Equable).
Northern Argentina. Spain. Southern U.S.A. Cape Colony.	Malta. Madeira. New Zealand. Tasmania.	Canada. Poland. Southern Siberia.	British Isles. Norway. Vancouver Isle. Falkland Isles.
↖ Italy. Greece.	↗	↖ North France. Holland. Belgium. West Germany.	↗

The Frigid, or Cold, Zones embrace all that lies between the Arctic and Antarctic Circles at $66\frac{1}{2}°$ N. and S. respectively, and the poles. They are largely regions of perpetual snow and ice, and might be divisible into *arctic* or *antarctic* and *polar*. A good example of a cold country is afforded by Greenland or Spitzbergen, where the heat of summer is too feeble to thaw out the frozen land surface.

XI. The Seasons.—In addition to the *rotation* of the earth upon its axis once every twenty-four hours, producing the alternation of day and night, there is also the fact that our planet makes an annual revolution round the sun, bringing about the successive changes in the seasons. Now, if the axis of the earth stood perpendicular to the plane of her orbit (or path she describes in the journey round the sun), there would be no such thing as summer and winter, and a very monotonous

state of affairs would ensue. It so happens, however, that the axis is tilted, or departs from the vertical by an angle equivalent to 23½°—in other words, that the axis, instead of being vertical to the plane of the orbit, is inclined to it at an angle of 66½°. This fact causes the phenomena of the *seasons*. A study of Fig. 4 will help us to understand this. At the spring or vernal equinox—*i.e.*, about March 21—the sun is vertical

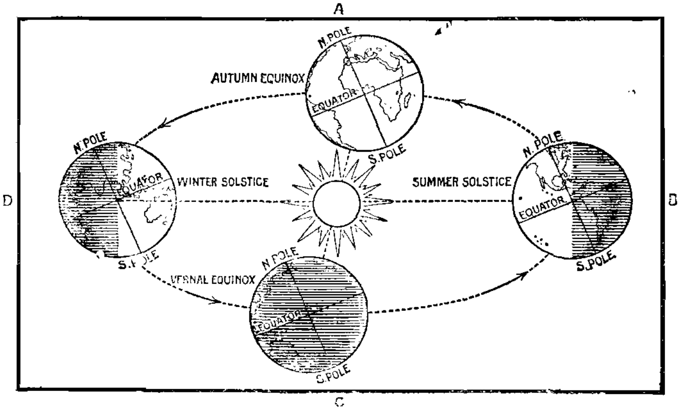


FIG. 4.—DIAGRAM OF SEASONS.

over the Equator, and day and night are equal, each twelve hours long all over the world. After this date the noonday sun becomes vertical at an increasing distance north of the Equator, till on June 22, the summer solstice, it is vertical at 23½° N. over the northern tropic line.

The length of the day at this period—midsummer for the Northern Hemisphere—increases as one goes northward. In London the days around June 22 are 16½ hours long—that is to say, the sun is above the

horizon for that number of hours; at Stockholm they are about 19 hours; in the north of Norway the sun does not set at all during the greater part of May, June and July (the land of the "midnight sun"), and at the North Pole the day lasts for six months, from the March to the September equinox.

Meanwhile, it is of course winter in the Southern Hemisphere, and the South Pole, being turned away from the sun on June 22, is in the middle of a night lasting six months. After June the days grow shorter in the Northern Hemisphere with the southward retreat of the vertical sun. At the autumnal equinox, about September 23, the sun is again vertical over the Equator, and day and night again become equal over the whole world. Around December 22, when the vertical sun is at its greatest distance, $23\frac{1}{2}°$, south of the Equator over the southern tropic, and giving summer to the Southern Hemisphere, the North Pole, being turned away from the sun, is in the middle of a six-months night, and the days all over the Northern Hemisphere are shorter than the nights, and get shorter and shorter as one passes from the Equator to the North Pole. In London the December days are only $7\frac{3}{4}$ hours long, as compared with $16\frac{1}{2}$ hours in June, and in the middle of the day the height of the sun above the horizon is only 15° in December instead of 62° as in June.

The orbit of the earth is not quite a circle, being what mathematicians describe as an *ellipse* with a small eccentricity, and the effect of this is that the earth is about 3,000,000 miles nearer the sun in January than in July (times of peri-helion and ap-helion respectively). The earth is therefore nearest the sun in the winter of the Northern Hemisphere and the summer of the Southern Hemisphere, but for various physical reasons

the effect is rather to increase the heat of the southern summer than to modify the cold of the northern winter. It happens, however, that at the time of peri-helion in the northern winter the earth must, in accordance with a gravitational law, travel with greater velocity round the sun than at ap-helion in the northern summer, and (as a result of this) the northern winter, the period when the days are shorter than the nights—that is, from September 23 to March 21—is a few days shorter than the summer, the period when the days are longer than the nights, March 21 to September 23, the reverse of course holding for the Southern Hemisphere.

As the surface of the earth requires time to get heated up and cooled down to the greatest amount, it follows that the hottest period of the year falls generally not at midsummer in June, but a little later—in July over the land, and as late as August over the sea. Similarly, the coldest month is usually not December, the mid-winter month, but January over the land and February over the sea. In consequence of this, the three usually coldest months—December, January, and February—do not completely coincide with the three months of shortest days—November, December, and January; and the three usually hottest months—June, July, and August—do not fit in with May, June, and July, the months of the longest days; and hence difficulty and confusion commonly arise when anything like a systematic attempt is made to classify the months of the year according to the seasons. Perhaps the most scientific way of attempting to divide the seasons is as follows:

Winter is the season of the year when the days are shorter than the nights, and comprises in the Northern Hemisphere roughly the six months October

to March, surrounding the winter solstice (about December 22).

Summer is the season during which the days are longer than the nights, and includes the six months April to September, surrounding the summer solstice (about June 22), when the sun is vertical north of the Equator.

Spring is the season of the year when the days are lengthening, and covers the six months January to June, surrounding the spring equinox (on March 21).

Autumn, or *Fall*, is the season, July to December, surrounding the autumnal equinox (on September 23), during which time the days are shortening as the vertical sun passes from the northern to the southern tropic. This is diagrammatically illustrated in Fig. 5.

This scheme, therefore, divides summer and winter into a spring and autumn half, making the first half of winter coincide with the second half of autumn, the second half of winter with the first half of spring, the first half of summer with the second half of spring, and the second half of summer with the first half of autumn. It is a *bi-phased* scheme of classification, and for various reasons is more precise, more logical and more useful, than the ordinary *single-phased* division of the year into four *successive* seasons, whose boundaries cannot be definitely fixed (see Bibliography).

Briefly we may define the seasons as follows:

Winter = period of short days and feeble sun, extending over the half-year October to March.

Summer = period of long days and powerful sun, extending over half-year April to September.

Spring = period of lengthening days and strengthening sun, extending over half-year January to June, and running concurrently with the second half

of winter and first half of summer. The strengthening sun and lengthening days cause the *spring* or rise of vegetation, and also to a certain extent of animal life throughout this period, but the

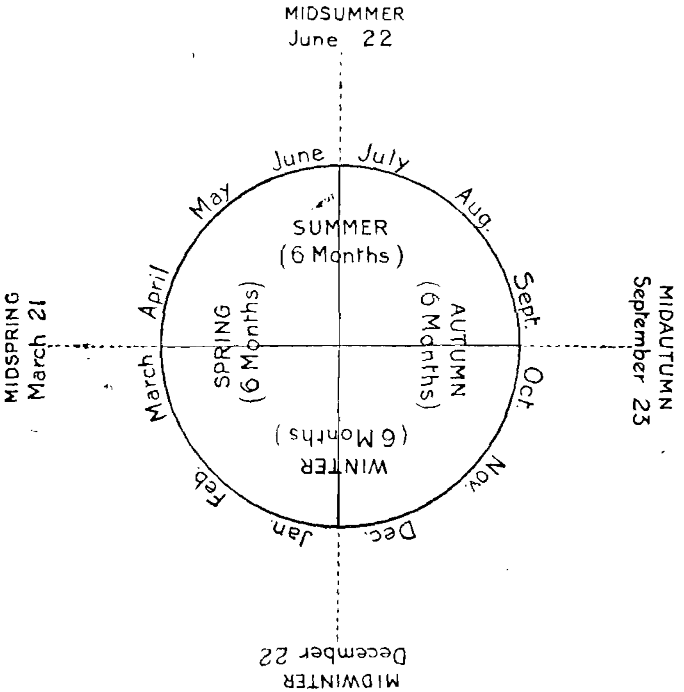


FIG. 5.

For the Southern Hemisphere this figure must be interpreted in the reversed sense.

earliness and rapidity of the "spring" of course vary with the warmth of the climate. Thus, in the northern latitude of Scotland May is the month when the most active growth of

vegetation occurs, but in the more southern climate of Italy March is the typical month of "spring."

Autumn = period of shortening days and gradually weakening sun, extending over the half-year July to December, and running concurrently, therefore, with the second half of summer and first half of winter. The word "autumn" literally means the *increase*—in reference to the harvest of corn, fruit and seed; but the term *fall* in antithesis to *spring*, as used in the United States of America and among country people in England, is a better name for this season, inasmuch as the decline in the amount of light and heat received from the sun brings about the *fall* of wild life. The colder the climate, the earlier, as a rule, is the advent of autumnal decay; and the fall of the leaves from trees of the same or similar species takes place later in southern than northern Europe.

XII. Climatic Change and Periodic Variation.—The question whether the climate of the whole earth, or of particular regions, is undergoing any progressive change in one direction or another, or is subject to periodic variation, is one that is constantly being discussed. Careful examination of meteorological records affords no indication of climatic change, and there is no evidence to show that the general climate of the whole earth has sensibly altered within *historical* times. The climate of England is probably very much now what it was in the days of William the Conqueror. Nevertheless there is evidence that, several centuries before the Christian era, parts of what are now the great desert regions of Asia and Africa were so much

better watered than now that they were the cradle of civilisation, a progressive desiccation having produced the present conditions of hopeless sterility.

Geological records, however, afford absolute proof that in prehistoric times—millions of years ago—the climate of the earth has undergone great changes. Thus, there was once a great Ice Age during which a great part of Europe, including the British Isles, lay under a sheet of ice, to the former existence of which large deposits of boulder clay and the marks of ice-wear left upon rock and stone bear ample witness; while fossilliferous remains show that subsequently to this animals and plants existed in the same region such as could only have flourished in a warmer climate than at present prevails. Many theories have been launched to explain these geologic changes of climate, but doubtless many causes have co-operated to produce them.

XIII. The Sun.—The *general climate* of the *earth* is of course fundamentally dependent upon the amount of heat and light which it receives from the sun at the distance of some ninety-three millions of miles.

It is estimated that the *heat* in the form of *radiant energy* sent annually by the sun to the earth would be sufficient to melt a layer of ice 100 feet thick uniformly spread over the surface of the earth. The quantity of heat radiated from the sun, however, seems not to be quite constant from year to year, but to vary within narrow limits in certain well-defined periods of eleven, twenty-three, and thirty-two years, in association with the phenomena of sun-spots and other manifestations of solar activity, which in turn have been co-related with variations of temperature and rainfall in India and other parts of the world. If the sun during one series of years does actually give out more heat to our planet

than in another series of years, the effect must certainly be to make the general climatic conditions over the whole earth proportionally warmer; but, as the variation is in any case comparatively small, such an effect is not very noticeable or conspicuous, and may be completely masked in any particular region of the globe by more powerful climatic influences.

CHAPTER II

TYPES OF LAND IN RELATION TO CLIMATE

I. The Earth's Surface Covering. — As one contemplates our planet, compelled inexorably to follow a prescribed path around the sun, and reviews all the complex variations of climate which occur on its surface, associated with the range of horizontal and vertical distance, the distribution of land and water, and the configuration of the coasts, the fact at once becomes apparent that the surface of the globe, enveloped as it is by an ocean of air, is under the direct control of climate; and the question how this control is manifested and reflected in the nature of the surface, at once opens out a wide field for careful study. The phenomenon which most strikingly and universally, perhaps, exhibits climatic control, is the earth's covering of vegetation; and we may, accordingly, take this for a text, as it were, to introduce the study of land types in relation to climate, using the distribution of vegetation as a rough criterion of the effects of climatic variations.

The three fundamental elements of climate, which all living creatures, plant or animal, irrevocably demand, and upon which their supply of food directly or indirectly depends, are **Light, Heat,** and **Moisture.**

Bearing this fact in mind, therefore—that the distribution of plants is regulated by the supply of these requisite elements—let us now, in a rough and general way, endeavour to classify the land surfaces of the globe according to a number of vegetation types. First of all, such main types may be recognised as **Forest, Grass, Desert**; and reference to the vegetation map of the world on p. 29 will show how the land surface of the globe may broadly be divided up into a number of zones, each characterised by some special form of vegetable growth.

II. Vegetation Zones. — (i.) A *Forest Belt* in the Equatorial region.

(ii.) A region of open *Grass Land*, called *Savana*, on either side gradually replacing the Equatorial forests.

(iii.) A zone of *Sand Deserts* succeeding the grass, and comprising much of the region situated towards the two tropical lines of Cancer and Capricorn at $23\frac{1}{2}°$ N. and S. respectively.

(iv.) *Grass Lands* again appearing north or south of the deserts according to the hemisphere, and in the interiors of the great continents of the Temperate Zones.

(v.) *Mixed Grass and Wood Land*, a wide zone embracing much of the temperate portion of the Northern Hemisphere, where the virgin forests have been cleared.

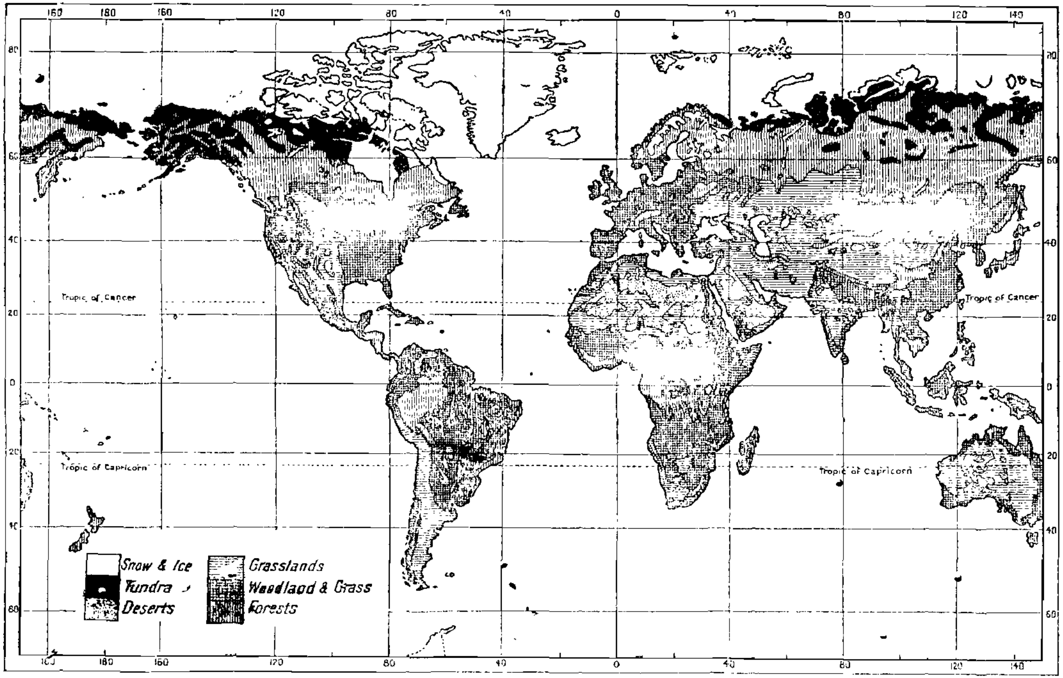
(vi.) A *Tundra Zone* towards the Arctic Circle.

(vii) *Snow Deserts* around the Poles.

Now, if one compares the vegetation map with the maps on pages 32 and 33, representing the average annual temperature of the air and the average annual amount of rainfall over the globe, one sees at once in a general way how closely dependent the growth of plants is upon the combined effects of heat and moisture. The supreme importance of light to plants in the exercise

of many of their functions is of course obvious on all sides. Different species require different amounts of light, as of heat and moisture, for their highest development, deficiency or excess alike exerting a prejudicial influence. It remains in this chapter to give a brief account of the vegetation zones, with some explanation of the meteorological régime under which they lie, and which has brought them about.

III. The Equatorial Forest Belt.—Wherever the Equator passes over land, it passes through an area of varying width, but commonly extending to 10° on either side of it, covered for the most part with dense, dark, impenetrable forest growth of a luxuriance to be found nowhere else on the earth's surface. The physical explanation of this fact is that the Equatorial region is the zone of highest average temperature and highest average rainfall, the combination of excessive warmth and wetness giving rise to the profusion of vegetable growth. The high mean temperature over the Equator depends upon the fact that the sun shines vertically over it twice a year—namely, at the equinoxes in March and September—and that consequently the Equatorial belt receives more heat from the sun in the course of the year than the margins of the Torrid Zone, bounded by the tropical lines, which only get the vertical sun once a year, in June or December, as the case may be. The high rainfall over the Equator is not so simply to be explained; it is due not to the fact that the Equatorial region is hot—inasmuch as many of the hottest parts of the globe are arid deserts, like the Sahara, Arabia, the Thar, and Central Australia—but to the fact that this region, as explained, is hotter on the balance of the year than any other part of the world. It must be remembered that the fierce rays of



VEGETATION ZONES OF THE WORLD.

the vertical sun evaporate large quantities of water-vapour from the surface of the oceans, lakes, rivers, and wet jungles of the tropics. As the air over the Equatorial region is slightly warmer than that a little on either side, it is more expanded, it is lighter or less dense—in other words, its pressure is reduced. A condition of unstable equilibrium ensues, and the hot, damp air over the Equator gets forced upward into higher regions of the atmosphere by the lateral pressure of the colder, denser air from north and south, which then flows in as Trade-winds towards the Equator to supply the deficit. When the heated Equatorial air gets into higher levels of the atmosphere, where the air is less dense than at the surface, it becomes at once relieved of a portion of its pressure, and accordingly expands and overflows. This process of expanding involves cooling of the air, and the consequent condensation of some of its abundant moisture into clouds and rain (see Chapter VIII., on Meteorology).

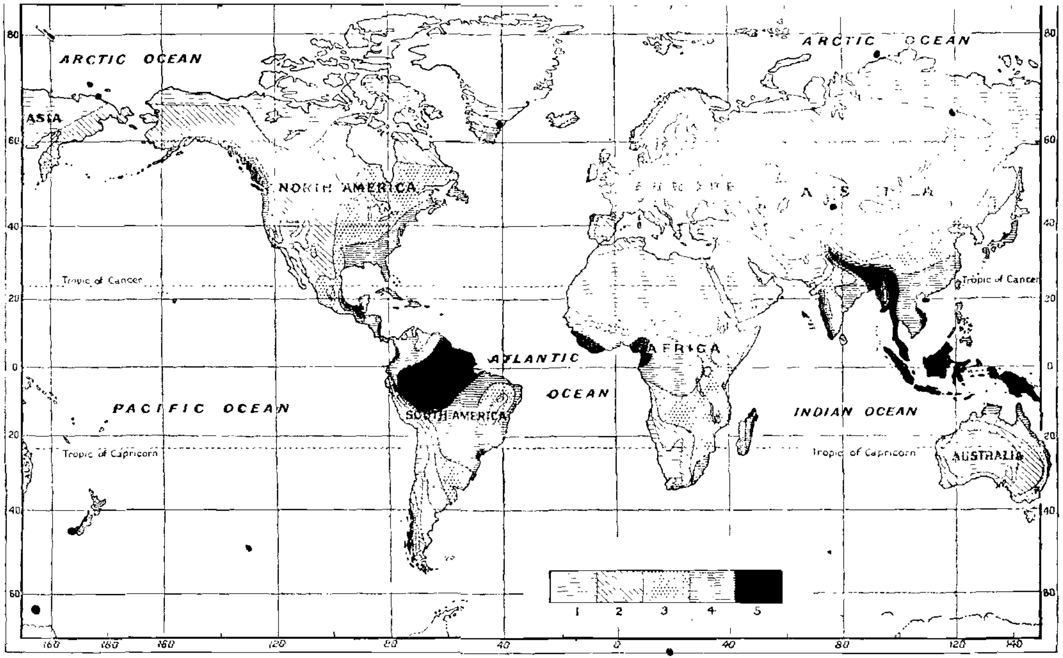
For this reason, then, or rather chain of reasons, the Equatorial belt is cloudy and rainy as well as hot, and so favourable to dense forest growth. This cloudy Equatorial rain-belt comprises what sailors have long known as the Doldrums—a much-dreaded belt in the days of sailing-vessels, because of the characteristic calm and stagnant condition of the atmosphere in it. The Equatorial rain-belt shifts with the sun north and south of the Equator, although not to the same distance, and gives one short rainy season to the outer portions of the Torrid Zone. The Equatorial region has two pronounced rainy seasons, but even during the drier season, when the rain-belt reaches its most northerly or southerly position, rain is common, the air is characteristically hot and steamy, and the sky often

covered with heavy thunder-clouds. It will be noticed from the temperature map that the heat-equator does not coincide exactly with the earth's Equator, but lies a little north of it. This is an effect of the greater *proportion of land north than south of the Equator.*

The average annual temperature in the damp Equatorial belt is about 80° F. The, temperature is fairly equable, the abundance of cloud and moisture seldom permitting it to rise much above 90° in the shade by day or to fall below 70° at night; nevertheless, on account of the damp atmosphere the natives are highly sensitive to the nocturnal cooling. Birds of brilliant plumage live in the tropical forests, poisonous snakes are numerous, and insect life reaches its maximum development—one might almost say an appalling development.

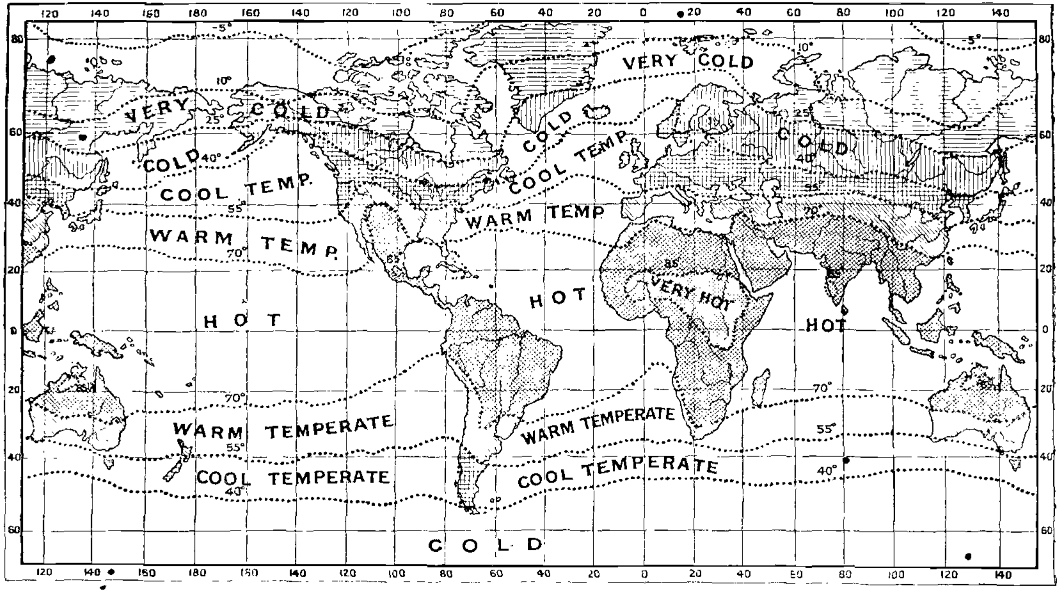
The forested region is peopled by native tribes in a low state of civilisation, like the Amazonian Indians, who live mostly along the river-banks. Agriculture is practised a little in the forest clearings, but what with the enervating effects of damp heat and the lavish manner in which Nature provides food in the tropics, the natives are but little constrained to active labour.

The chief economic value of the Equatorial forest-belt is in the forests themselves, which supply valuable woods like mahogany and ebony, saps like rubber, quinine, and various other powerful drugs. The great commercial productivity of the forests has attracted a considerable white population to settle along their margins and along the rivers. Along the lower Amazon and its tributaries, for instance, plantations of sugar, coffee, rice, tobacco, etc., have thus been made, and sugar factories and rice mills erected; and the intercourse with the outer world thus established in the



MEAN ANNUAL RAINFALL OF THE WORLD.

Rainfall in inches: 1, Under ten; 2, ten to twenty; 3, twenty to forty; 4, forty to eighty; 5, over eighty.



MEAN ANNUAL TEMPERATURE OVER THE EARTH IN DEGREES FAHRENHEIT.

interests of trade and commerce has brought civilisation to the very doors, as it were, of the gloomy forests, as manifested by the uprise of such large cities as Para, Manaos, and Pernambuco.

IV. The Tropical Grass-Lands.—As one moves farther away from the Equator to the north or south, the effects of diminishing rainfall become more and more apparent in the thinning of the forests and replacing of them by open stretches of grassy or scrubby growth, which gradually widen out into vast grassy tracts called *savanas.* These open grassy plains include much of the Sudan, Venezuela, where they are called *llanos*, Brazil (campos), and Australia (downs). Climatically, the grass zone is distinguished from the forests of the Equator in having a long dry season and a short wet season occurring at the time of, or soon after, the vertical sun, with greater extremes of temperature between day and night, winter and summer, and a somewhat lower average of temperature consequent upon the increase of latitude. The savanas are naturally valuable for grazing purposes, since the prolonged heat and drought of the withering dry season convert the grass cover into natural hay. They are also well adapted to agriculture along the Equatorial margins, where the rainfall is more abundant, or where irrigation operations can be carried on. In this zone, however, the rainfall is very variable and uncertain from year to year, and the population is subject to the scourge of drought and famine. The grass belt is, on the whole, much healthier and better adapted to human life than the forest belt, and promises to support a growing population as the arts and industries of modern civilisation encroach upon the area, and assist in turning the soil to good account. The African

savanas are commonly infested with lions, and abound —or did abound till quite recently—with elephants, rhinoceroses, giraffes, and antelopes.

V. The Monsoon Systems.—Before considering the next vegetation zone entered upon in receding from the Equator—namely, the great sand deserts, which more or less girdle the globe at the margins of the tropical zone —it will be necessary to refer to a very important and remarkably interesting modification of climatic conditions which is set up in certain regions in the tropics, and also outside the tropics, by the system of winds known as the *monsoons*. The term "monsoon" is, strictly speaking, applied to a seasonal deflection or alteration in the normal wind circulation, brought about by marked inequalities of temperature between land and sea. In winter the surface of a great land area becomes colder than that of a surrounding or neighbouring sea, with the result that the air over it sinks and accumulates, and then, by reason of the increased atmospheric pressure, begins to flow outwards towards the less dense air over the sea; whilst in summer, on the other hand, the land being hotter than the sea, the air over it expands, and draughts of air or wind-currents are drawn in over the land from the higher pressure over the sea. In this way the various currents due to the normal atmospheric circulation may be either strengthened or weakened, or deflected into another direction, in consequence of this monsoon influence being superimposed upon them. The most powerful monsoon winds and their most important effects upon vegetation occur in the Torrid Zone. Near the Equator, where summer and winter heating and cooling do not take place, the land is permanently hotter than the sea, and the effect of this is seen to advantage on the

west coast of Equatorial Africa, where the South-East Trade-wind of the Atlantic Ocean is deflected towards the African coast the whole year round, and thereby converted into a south-west wind. But the most important monsoon system in the world is the great Indo-Australian one, together with that of Central Asia (see Chapter IV.). The economic importance of the annual rain-bearing South-West Monsoon to India is paramount, inasmuch as without it the country would be largely uninhabitable desert, the bulk of India lying too far north to receive the abundant rains provided by the seasonal shift northwards of the Equatorial rain-belt. The phenomena of land and sea breezes—the on-shore breeze by day and the off-shore breeze by night—so conspicuous in settled summer weather, are in reality monsoons on a small scale.

VI. The Great Sand Deserts of the Globe.—Along the margins of the tropical zone, and extending to about latitude 30° N. or S., the average climatic conditions may be described as nearly rainless, and it is in this belt that most of the great sand or rock deserts of the earth are situated. In the Northern Hemisphere we have the Thar in North-Western India, the great Persian and Arabian deserts, the vast wilderness of the Sahara and Egyptian deserts, and the arid States of Arizona, Utah, and Mexico in North America. In the Southern Hemisphere, first and foremost is the great desert of Central Australia, then comes the dry Kalahari tract of South Africa, and finally, in South America, the desert coastal strip of Northern Chili and Southern Peru. The question, therefore, immediately arises, Why are these deserts there? The fact of their being arranged in a regular series parallel to the Equator suggests a common cause, and whilst many

factors predisposing to rainless conditions must co-operate to produce desert areas, the primary and original cause of each of them is their position in the Trade-wind belt, so that they may appropriately be designated the *Trade-wind Deserts.* The Trade-winds (Chapter VIII.) are compelled to blow from the north-east in the Northern Hemisphere and from the south-east in the Southern to supply the deficit of atmospheric pressure caused by the uprise of hot moist air over the Equator. Since they are travelling from colder to warmer latitudes, and tend to descend close to the earth's surface rather than rise up into higher levels, they are constantly being dried and enabled to hold more and more moisture in the uncondensed state; and where as in Northern Africa (see Chapter IV.) they have to blow over a vast flat land surface that is already, for various geographical reasons, very dry and cut off from oceanic moisture-bearing winds, the resulting aridity is such as almost completely to stop the growth of vegetation, except in certain spots, called "oases," favoured with a subterranean water-supply.

The fearful droughts giving rise to the desert interiors of Australia and Africa are intensified, especially in the case of Australia, by the mountain barrier along their eastern coasts, which, meeting the South-East Trade blowing off the moist ocean, forces the wind upwards, thus cooling it, with the production of clouds and heavy rain on the eastern slopes of the mountains, so that when the Trade-wind descends the other side of the range and flows over the interior of the land, it is not only deprived of much of the moisture it previously held, but is further dried by being warmed again in its descent. In South America there is no important desert region east of the Andes, because the vertical

relief of the surface is such as to cause the condensation of a certain amount of moisture from the in-blowing South-East Trades, and on the eastern upper slopes of the Andes the rainfall is often large. But here again, as in the case of Australia, the air of the Trade, in descending the western side of the huge mountain wall of the Andes, is further warmed and dried; and as, moreover, the cold Antarctic drift current keeps the coastal lands of Southern Peru and Northern Chili very cool, and the lands themselves are not wide enough to become sufficiently heated up by the sun to draw in rain-bearing monsoon winds, a long strip of true desert extends along the coast from near the Equator to 30° S.

In areas not entirely destitute of vegetation, the typical species of plants may be called desert flora—*i.e.*, such as are physiologically adapted to withstand excessive drought, and possess what botanists call a *xerophilous* structure. They are, for the most part, succulent thorny shrubs, able to store up quantities of water—in the stem like the cactus, or in fleshy leaves, like the agave—and have all sorts of devices for minimising the loss of water by transpiration through the leaves into the dry desert air.

The characteristic quadruped and beast of burden in the deserts of Africa and Asia is the camel. The excessive evaporation of surface water, resulting in the complete desiccation after the lapse of time of desert regions, has left deposits of salts as an efflorescence upon the surface, such as nitre and borax. The nitre or saltpetre deposits of Chili have great commercial value, and have consequently attracted workers to the arid and inhospitable district of Iquique. Desert tribes of men are nomadic on account of the severity of external conditions and difficulty in obtaining the means of subsistence, but the dry bracing air of the desert has

a stimulating effect upon the nervous system, and a desert climate is far from being unhealthy. The diurnal range of temperature is very large. The highest known shade temperatures on the surface of the earth, from 110° to 130° F. or higher, occur in the marginal tropical deserts during the hottest hours of the day in the summer months, whereas over the moist Equator the temperature rarely reaches 100°, although the average or mean temperature of day and night throughout the year is higher at the Equator.

VII. The Forests, Grass Lands, and Deserts of the Temperate Zones.—The location of the Trade-wind deserts which we have just studied, abundantly illustrates the fact that vegetation cannot grow luxuriantly under the influence of high temperature without adequate rainfall. The forests, savanas, and deserts of the tropics, arranged roughly in parallel belts round the globe, exhibit a close relation to latitude; but the types of vegetation prevailing in the temperate regions are rather more *definitely associated with the arrangement* of the continents and the accessibility of the *various regions in* them to moisture-laden winds than to the parallels of latitude.

Referring to the map on page 29, we see that practically all parts of Europe, Asia, and America, situated in the Temperate Zone are described as regions consisting of mixed forest, grass, or cultivated land wherever the rainfall is moderately great. In primeval times most of the European countries, including the British Isles, were covered with dense forest composed of different species of trees from those of the tropical forests, adapted to the cooler climate, forest growth being the cover natural to the European climate; but the progress and development of civilised man, who

reigns supreme in the temperate parts of the earth alone, have in course of time involved the cutting down of great tracts of virgin forest to make room for the growth of cities wherein he can dwell on the one hand, and for the tilling of the soil to supply his food on the other, the Temperate Zone forests affording little material for the means of healthy subsistence. Where the forests have been cleared, and the soil left uncultivated, grass grows spontaneously, furnishing grazing ground for the cattle and sheep which supply civilised communities with the extra animal food which life in colder latitudes inevitably calls for. Thus it is that through human agency the ancient forests have largely disappeared and given place to a surface diversified by *wood* (replanted or remnant of forest), *grass*, and *agricultural land*, such as characterises the land of the great nations of the world—Britain, France, Germany, the United States, etc.—wherein have sprung up mighty cities intercommunicating freely and rapidly as a result of the splendid triumphs of modern engineering science.

This privileged area of mixed grass and wood does not, however, extend over the whole of the land surface of the Mid-temperate Zones. There are vast tracts in the interior of Asia, in Southern Russia, in the United States immediately to the eastward of the Rocky Mountains, and in Argentina, where forest growth is prohibited by deficiency of rainfall, and where grasses alone can flourish. The wetter of these dry regions are favoured with a rich growth of wild grass valuable for grazing purposes, such as the North American *prairies* and the *pampas* of the Argentine; but the drier are only able to support a covering of thin and poor herbage, or patches of a stunted, scrubby growth. These semi-desert areas are known as *steppes;*

they characterise much of South-Western Asia, the south-east of Russia, portions of Hungary, and the interior of Spain. In the driest regions of all the steppes pass into true deserts, as in the great inhospitable tract called Gobi, or Shamo, in Mongolia; the stern and desolate elevated plateau of Tibet; and the sandy wastes of that portion of the United States of America, situated between the mountain ranges of California and the Rockies, known as the Great Basin.

The continental interiors naturally tend to be dry, and the rainlessness of the special areas above mentioned is due largely to their being cut off by mountain barriers from rain-bearing winds.

The middle latitudes of the Temperate Zones lie in the course of a current of westerly winds, the *Anti-Trades*, representing the overflow of the air which rises over the Equator, and, cooling down, descends to the surface of the earth in middle latitudes. In the Southern Hemisphere these westerly winds—"The Brave West Winds"—are regular and constant because of the absence of disturbing land masses, but in the Northern Hemisphere they are very uncertain, and the general westerly drift of air is liable to be broken up by eddies of alternately low and high pressure, known as cyclones and anticyclones respectively (Chapter VIII.). The weather of the Temperate Zones is thus very variable, and marked by sudden changes, whilst the contrast between summer and winter, involving the periodic alternation between heat and cold, light and darkness, is very pronounced. These conditions prevent Nature from wearing a monotonous aspect, as in the tropics, where the seasons are not well marked, and the weather is more regular, and they serve as a stimulus towards human activity, both physical and mental.

VIII. The Tundras.—In the Northern Hemisphere, where land borders on the Arctic Circle, as in Europe, Asia, and America, a type of land prevails known as the *Tundra*. The tundras are vast plains where the soil is permanently frozen to a great depth. The peculiar feature of the tundra region is the extraordinary contrast which the surface presents between winter and summer. During the long, bitter, arctic winter the tundra is a great snow desert, compelling the nomadic tribes which dwell on it, such as the Lapps and Samoyads, to journey about either by dog or reindeer sledge, or on skis. In summer, however, when there is perpetual day for many weeks in succession, the heat of the sun thaws out the surface of the soil, converting it into a swamp, or in places even drying it up, and then instead of the dreary waste of snow there appear mosses, lichens, ferns, whortleberry bushes, various coloured flowers, and a pest of mosquitoes which would rival any to be endured in Southern Italy. Stunted birch and willow trees grow along the water-courses, and while towards the south the tundra merges into the northernmost forests of the Temperate Zone, on the north it passes into the great snow and ice deserts of the inner polar regions. The men of the tundras live by fishing and hunting, and on the milk and flesh of the reindeer.

IX. The Polar Snow Deserts.—The two Frigid Zones, embracing the areas between the Arctic and Antarctic Circles and the Poles, are largely deserts of perpetual snow and ice, the heat of the summer not being sufficient or long enough to melt away the snow cover. Vegetation can only flourish for a few weeks in June, July, or early August, when the mean temperature of the air exceeds freezing-point and the sun never sets.

Stunted, miniature forms of birch and willow and various arctic flowers then appear here and there in the milder parts; but when the cold of winter suddenly sets in again towards the middle or end of August, the plants become frozen hard and die down. Perhaps the most important fact we know concerning the polar regions is this (a fact confirmed by the recent expeditions of Peary and Shackleton)—that the North Pole is in a sea area covered by floating ice, and the South Pole in an elevated land area buried under thick masses of ice and snow. Whilst, however, the South Polar continent is an island, the North Polar Ocean is nearly landlocked. Typical arctic countries are Spitzbergen, Nova Zembla, Franz Joseph Land, and Greenland (see Chapter IV.). The Eskimo who inhabit these countries along the shores of the Arctic Ocean depend for food and clothing upon arctic animals, such as the reindeer, seal, whale, and polar bear. They are by no means a degraded race, but the severity of the cold and the consequent hardness of life prevent them from developing a high grade of culture. The atmospheric conditions near the Poles seem to be drier and less windy than those prevailing on the margins of the Frigid Zones, or in the colder parts of the Temperate Zones. Both Poles are centres of *relative* high barometric pressure—not of low pressure, as used to be thought—from which the air flows outward towards the lowest pressure at the margins of the Frigid and Temperate Zones; but the South Polar high pressure system is more marked and constant than the North Polar, where the irregular distribution of land and water makes the pressure distribution more variable and complicated.

X. The Mountains.—Wherever the surface of the

earth is uplifted into mountain-chains, broad plateaux, or hill ridges, a change in the character of the vegetation marks the ascent into a colder climate. We have already seen how high mountain masses in the tropics exhibit from base to summit all the vegetation zones that occur from the Equator to the Poles. Amidst the snows of the Alpine summits many beautiful little plants with flowers to match their snowy surroundings, such as the well-known *edelweiss*, grow on rocky eminences, and some of them occur also in Spitzbergen and other polar countries. The Alpine pastures below the snow-line are peculiarly vivid, and the grass covering of much of the mountains of warmer climates is fresh and luxuriant to a degree seldom found in the lowlands. In this connection Ruskin reminds us of the meaning of those words of the 147th Psalm: "He maketh grass to grow upon the mountains." Since mountains, by forcing upwards and cooling currents of air which blow against them, provoke rainfall on their windward slopes, it is frequently observed that mountains arising out of desert plains have their slopes clothed with forests. The Rockies of North America and the Andes of South America afford instances of this along portions of their length, whilst isolated plateaux and mountains in the midst of the Sahara Desert stand out elevated oases as a result of the local rains they give rise to.

XI. Adaptive Types.—The vegetation forms characteristic of the various zones above described group themselves into what botanists call a number of adaptive types—that is to say, they are adapted to climatic conditions. Whilst the plants belonging to a special type have certain characteristics in common, the species composing them differ widely in different

parts of the world. Not only are the trees of the temperate forests, for example, entirely different from those of the tropical, but the separate species have often a very restricted range. Thus, in the forests of Northern Europe, evergreen trees of the conifer tribe predominate—*e.g.*, pine, spruce, silver fir, larch, as in Northern Scotland, Sweden, and Northern Russia; in Central Europe the forests and woods consist mainly of deciduous species—oak, beech, ash, and elm, as in England, France, Germany, etc.; whilst in the warm Mediterranean regions of Southern Europe the prevailing trees, except on the mountains where the forests of Central and Northern Europe prevail according to elevation, again tend to become evergreen, like the holm oak, holly, olive, orange, lemon.

XII. Reaction of Vegetation Zones upon Climate.—If climate controls, and originally produced, the different zones of vegetation, the vegetable covering itself reacts, to a certain extent, upon the climate, till at length a permanent state of equilibrium is established, which holds so long as the existing conditions last. Thus, if drought gives rise to deserts, the deserts themselves react upon the arid conditions and intensify the drought, besides producing large variations of temperature.

Similarly, if heat and moisture nurture the Equatorial forests, the forests themselves keep the air moister and more equable in temperature than would otherwise be the case.

CHAPTER III

WELL-KNOWN LANDS DESCRIBED IN RELATION TO CLIMATIC CONTROL

PART I. BRITISH ISLES

1. **Scope of the Inquiry.** — Pursuing the subject-matter of the last chapter in closer detail, we have now to describe the climatic conditions of a few selected countries representative of the different regions of the earth, and see how the vegetable covering and general appearance of the surface of such countries are controlled by them. We will take the following:

1. The British Isles, to illustrate the effects of a cool-temperate, moist, marine climate (forming the subject-matter of the present chapter).
2. Russia, to illustrate the effects of a cool-temperate, dry, continental climate.
3. Italy, to illustrate the effects of a warm-temperate climate, neither markedly insular nor markedly continental in character.
4. Egypt, to illustrate the effects of a Trade-wind, sert climate.
5. India, to illustrate the effects of a monsoon mate.
6. Brazil (Amazon Basin), to illustrate the effects of moist Equatorial climate.

7. Greenland, to illustrate the effects of a frigid climate.

II. Preliminary Remarks: Factors other than Climatic.—Whilst the covering of the earth's surface over hill and dale is primarily under the control of atmospheric conditions, it must be remembered that there are other influences at work besides the climatic. The prevailing type of vegetation in a given locality, not to mention its general fertility or barrenness, depends also upon the nature of the *soil*, *i.e.*, upon the *edaphic* factor; and the soil itself is born of rocks through the process of *weathering* (Chapter VIII.)—depending, therefore, upon both the geology and the climate of a district—and is liable to transport by rivers, glaciers, and wind. In reading the climate of a country, therefore, in its general vegetation, we must always be mindful of the special local character of the soil, and be ready to disentangle as far as possible its influence from the general effects of climate. Near London, for example, there are characteristic differences of vegetation associated with the different geological formations, for which slight local climatic variations are in no way responsible. Thus, the chalky soils of the Chiltern Hills and North Downs, which enclose the Lower Thames Valley, on the north and south respectively, support a soft green turf, suitable for sheep pasture, or are clothed with beech-woods; whilst, on the other hand, the sandy ridges and plains are marked by those extensive, but broken and beautiful, tracts of heath and pine which cover the bracing Hindhead uplands and so much of Western Surrey and Northern Hampshire.

Another important factor to be considered is the *economic* or *political*, giving rise to those artificial changes in the scenery of a country associated with

the occupations of men—industry, forestry, agriculture, engineering, building, etc.

Thus, although England is climatically rather a pastoral than an arable country, yet both the climate and the soil would permit of much more wheat-raising than is actually practised; and amongst the reasons for this are the economic factors which have led to the decline of British agriculture, and the political factors which have been responsible for the preservation in their wild condition of the large estates of the nobility, enclosing magnificent parks, full of rugged, tangled woodland, in nearly every English shire.

III. 1. General Description of Climate.—The British Islands, situated as they are between the 50th and 60th parallels of north latitude in the belt of mixed wood and grass land, possess a climate which belongs to the colder portion of the Temperate Zone. Again, placed on the verge of the Atlantic Ocean (with its supplies of warm surface water brought northwards by the Gulf Drift), in the path of strong west-south-westerly winds that are kept warm by passing over this ocean, they enjoy a moist, equable climate, considerably warmer than is due to their high latitude. The mean annual temperature at sea-level is about 48° F., ranging from 45° in the Shetlands to 53° in the Scilly Isles, and the mean annual range of temperature between summer and winter is about 20° F.—under that along the west coast, and over it in some of the more inland and eastern parts. In winter the isothermal lines, or lines of equal mean temperature, run nearly north and south, while in summer they traverse the country from east to west, the main source of heat being the Atlantic Ocean in the former case and the sun's rays in the latter. On some ten or twelve days during the

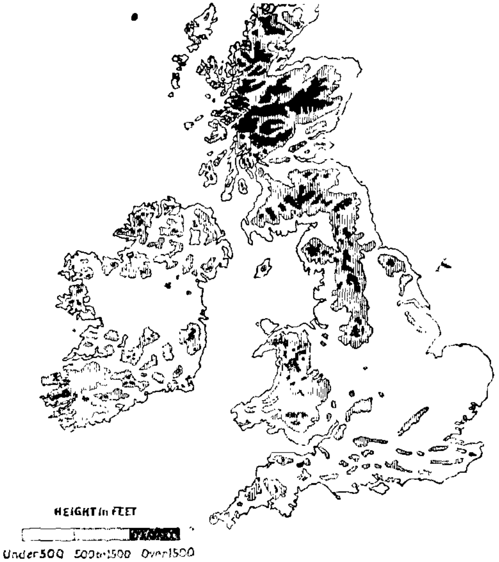
summer the afternoon temperature may be expected to approach 80° in the shade, and in the warmer parts of the country it occasionally exceeds 90°; whilst during the hardest frosts of winter the night temperature commonly drops to 15°, and in the colder parts occasionally falls considerably below zero. But it is rare that the temperature of the air remains as much as 10° below the freezing-point for more than a few hours together.

Owing to geographical position, the rainfall is large for the high latitude, and is evenly distributed throughout the year; the amount averages over 40 inches annually in the western parts of the kingdom, and under 30 inches in the eastern. In certain of the very wet hill districts (compare the maps on p. 51), such as the Western Highlands of Scotland, the English Lake District, the Pennine Moors, the Welsh mountains, the Cornish heights, and the Killarney district of Ireland, the rainfall varies from 50 to 150 inches, and locally even exceeds 200 inches. These districts, which are the wettest in Europe, and amongst the wettest in the world, owe their high rainfall to their peculiar topography—to the obstacle presented by the hills to the passage of the moist south-west winds from the Atlantic Ocean, whereby they are forced upwards, with copious precipitation as a result. The snowfall is variable and uncertain, as regards both time and locality; and, owing to the fact of the mean winter temperature being several degrees above 32° F., much of the winter precipitation takes the form of rain. Nevertheless, the amount of snow which falls frequently in the northern portions of the kingdom, and occasionally in the southern, especially in the elevated moorland districts, is very great, as indeed is inevitable in a country lying so far north.

The British Isles have a cloudy, and consequently rather sunless, climate. The south coast of England is the part most favoured with sunshine; but trustworthy sunshine records show that all round the coast there is on an average more sunshine than in the interior of the country, an effect probably due to the high winds along the coasts, which tend to scatter and dissipate the clouds and mists supplied by the sea and drive them inland, to settle in a more stagnant atmosphere. Severe gales, associated with the passage of large and steep barometric depressions of a cyclonic nature, are very common during the cold season of the year; and, despite the close vigilance kept all round the coast by coastguard and lighthouse men, and the ready assistance always at hand in times of stress, the annual death-roll from the wreckage of small craft at sea is a long and melancholy one. The thunderstorms of the warm season are less frequent and violent in Britain than in most of the continental countries of Europe, but from time to time during the summer they are liable to develop locally in a somewhat dangerous form, and some localities are more liable to these visitations than others. Dense fogs may occur inland in winter and round the coasts at all seasons. The *smoke fogs* of London and the great industrial centres of the North and Midlands, being of highly obnoxious character, are considered to be more prevalent than they really are. London fog requires, among other conditions, a dead calm for its formation; and as the atmosphere is very rarely calm in winter, serious fogs are actually by no means common, although liable to occur on three or four days in the course of an average winter.

In regard to the comparatively equable temperature, the moist atmosphere, and open winters, the climate of

MEAN ANNUAL RAINFALL OF THE BRITISH ISLES.



BRITISH ISLES: OROGRAPHICAL.

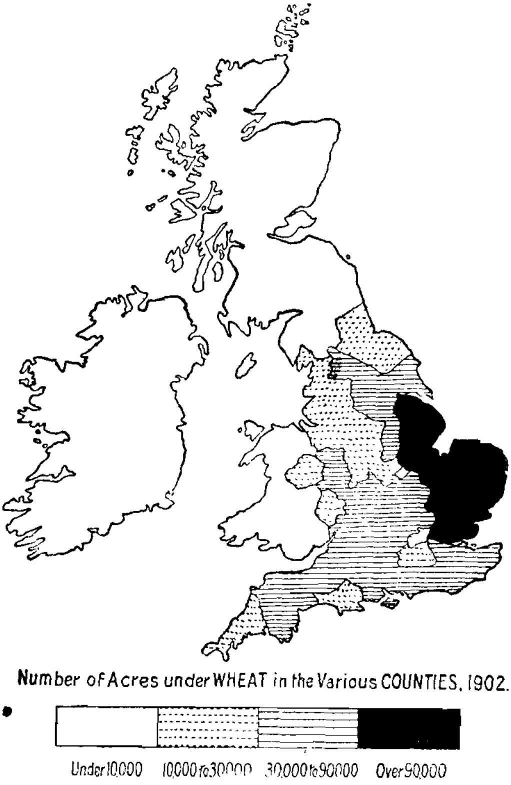
The rainfall-map shows (1) the general decrease of rainfall from west to east; (2) when compared with the orographical map, the increase of rainfall with the height of the land.

the British Isles may be called mild; but in other respects the climate is severe, being harsh and damp, and it is characteristically northern, with violent blasts and hard grey skies, broken and relieved by rapidly changing cloud-effects often of great beauty.

III. 2. The Climate of Britain as reflected in her Landscape.—The peculiar freshness and verdure of the vegetation of the British Isles, which give a distinctive note to the colouring of the landscape, are essentially the product of three climatic conditions—(*a*) an equable temperature, (*b*) a moist atmosphere, (*c*) an abundant rainfall. The two first, acting together, are of more importance in the result than the actual amount of rainfall. Even in the east of England—in Suffolk and Norfolk, for instance—over a large part of which the annual fall is only a little over 20 inches, or about the same as in the brown arid steppes of Hungary, the green meadows and fresh woods still persist, although, of course, the grass is not usually of that vivid emerald hue which so delights the eye in the rainier west of England and Ireland, especially among the hills where the rainfall is excessive. The factors that are of primary importance in this respect are the cloudy skies and moist atmosphere, with the humidity averaging about 80 per cent. of complete saturation of the air, together with the *frequent* rain evenly distributed over the year (independent of the actual amount), and the relatively small range of temperature between summer and winter.

The moist, open winters are favourable to tree growth of large size, and magnificent specimens of oak and beech grow in the lowlands all over the country—except the north of Scotland, where conifers replace most deciduous trees—but especially in Hampshire,

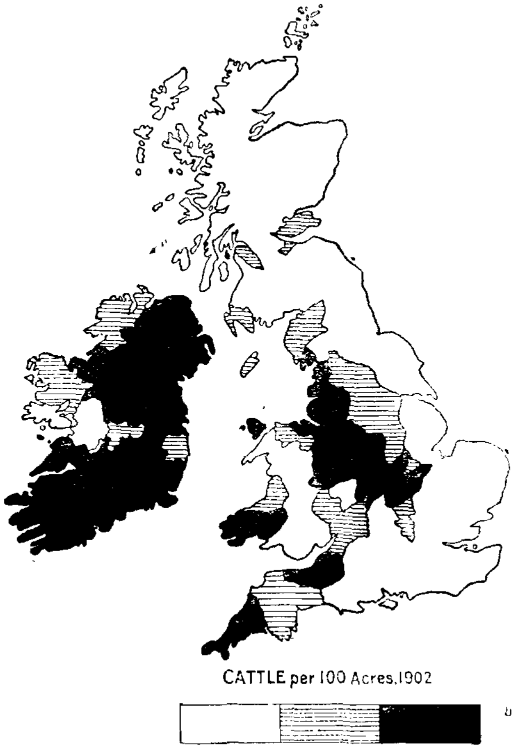
Berkshire, and other counties in the south of England, which seem to be precisely in the climatic zone most favourable to trees. On the other hand, in virtue of



THE CHIEF AREAS DEVOTED TO WHEAT IN THE BRITISH ISLES.

the same climatic dispensation, the land is poor in "fruit" produce; the comparatively cool and sunless summers prohibit the ripening of many edible fruits which grow with great luxuriance on the Continent.

Thus the lowlands of Britain present a highly fertile and cultivated appearance, except in the far north. There excessive cold and wet cause large areas to



THE CHIEF AREAS DEVOTED TO CATTLE IN THE BRITISH ISLES.

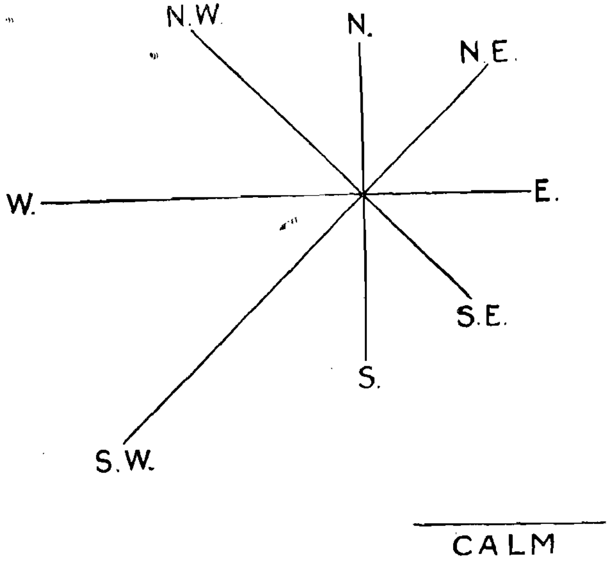
degenerate into barren moorland, unless very strong efforts are constantly made to cultivate the soil, and even such hardy crops as oats and potatoes are difficult to raise. But the least elevation immediately tells

upon the surface of a country situated so far north, and the British hills and mountains, at altitudes which permit of forest growth in the latitude of the Alps, are characteristically bleak and barren, supporting, as a rule, where the surface is not bare rock, only heather *or coarse herbage, on which the hardier breeds of* sheep pasture. In all elevated regions stone walls replace hedgerows, and in all exposed localities the trees are bent towards the east, indicating the predominance of strong westerly winds.

The two maps on pp. 53 and 54 show the control of climate upon the localization of two great British farming industries—wheat-growing and cattle-raising—the former thriving on flat land where the climate is normally dry, the latter on flat land where it is wet.

There is another pleasing characteristic of English scenery, depending in great measure upon the moist, equable climate (the absence of which is very noticeable in much continental scenery), and that is the harmonious manner in which the smaller elements of country landscape are blended together. In the more extreme continental climates of Belgium and Eastern France, for example, there is seen a tendency towards a severe separation of such landscape elements as wood, grove, thicket, meadow, and cornfield; and the trees, where *not artificially planted in rows, show a greater inclination* to grow clumped together than to stand free and isolated, as though for mutual protection from fierce sun or nipping frost. But in England the meadows, the cornfields, heaths and woods, intermingle over hill and vale in wild, picturesque confusion; and the very thrush species, which in Switzerland sing only in deep woods, here, finding abundance of green cover, warble round the homesteads in the company of men. It is

this quality of landscape—largely, though not perhaps entirely, the effect of climate—which makes rural surroundings in England so charming and suitable for residence, and which has doubtless helped to nurture



S.W.	..	=	18·4	100·0
W.	..	=	16·8	
N.W.	..	=	12·1	
N.E.	..	=	9·5	
S. ..	..	=	8·9	
E. ..	..	=	8·5	
N. ..	..	=	7·9	
S.E.	..	=	7·8	
CALM	..	=	10·1	

in the English people that love of country life and sport which they have always so strongly manifested.

III. 3. Wind-Direction.—The annexed diagram illustrates the percentage frequency of winds from different

directions in the British Isles on the average of the whole year. It will be seen that the prevailing wind-direction may be called west-south-westerly, and that the wind blows more frequently from the western than the eastern half of the compass. The relatively high percentage of north-east wind is due to the months of March and April, when this wind is common. The figures have been obtained by courteous permission of the Royal Meteorological Society, which conducted an investigation upon the subject for the twenty-five years, 1881 to 1905.

III. 4. Special Regions of the British Isles briefly considered in Relation to Climatic Control.—*Cornwall and the South-West of England.*—The climatic conditions of Cornwall and their effects are highly peculiar and interesting. Projecting as a narrow peninsula into the warm northward-drifting surface waters of the Atlantic Ocean, and subject to the full influence of the prevailing south-west winds, the county enjoys an extremely mild and equable temperature, together with a high rainfall; but at the same time it suffers unduly from bleak and tempestuous sea-winds, and these two conditions are productive of somewhat incongruous results. Thus, while the mean winter temperature is high and equable enough to allow delicate subtropical shrubs, like the myrtle, hydrangea, and fuchsia, to flourish in the open air all the year round with great luxuriance round Falmouth, Penzance, and other sheltered localities, the high salt-laden winds are very inimical to larger growth, so that fine trees in Cornwall are very scarce, and only to be found in the more sheltered and deeper valleys; and even there they lack the dimensions of those to be seen in many other shires.' In the wild wind-swept granite country of the Land's

End district, for example, one may often see a delicate hydrangea plant flowering luxuriantly in front of a bare, grey farm-house, whilst not a tree worthy of the name can be seen for miles around. The winter gales, which occur with such violence, not only raise tremendous seas against the rugged, cavernous coast-line, but carry the salt spray right over the bleak, high moorlands of the interior of the county, blighting the budding leaves in spring wherever it reaches; and the whole landscape of Cornwall spells *wind:* the farm-houses stand desolate and bare, the churches are built low, the very tombstones in some districts require to be supported with heavy masonry; trees are scarce and diminutive, and stone is more prominent in the hedgerows than wood.

Although the winters are warm and suitable for certain classes of invalids, with a mean temperature of over 40° F., Cornwall is now and then taken by surprise in the matter of severe frost and snow, and the great "west-country" blizzard of March 9 and 10, 1891, one of the worst snowstorms that have ever raged in the British Isles, would have done justice even to the Scottish Highlands.

The Scilly Isles, some forty miles south-west of Cornwall, are literally bathed in warm, humid Atlantic air, and are the only part of the British Isles where hard frost is unknown; they grow daffodils and early spring vegetables for the London market. Devon has a similar climate to Cornwall, but as the land here begins to broaden out, the extremes of temperature are greater, the summers drier and hotter and more favourable to agriculture and fruit-growing. The wild granite plateau of Dartmoor has an excessive rainfall, sudden dense wet mists, and in winter often deep and lingering snows.

Kent and the South-East of England.—The south-eastern *corner* county of England offers some remarkable contrasts to the south-western *corner* county from a climatic point of view. Lying farther east, and close to the Continent, Kent has a drier and more extreme climate, and the landscape unites in a singularly luxuriant and beautiful manner the verdant pastoral characteristics of the west of England with the agricultural productiveness of the east. Whilst the *early* spring is more forward in Cornwall than in Kent, the *late* spring is more forward in Kent, owing to the greater rapidity with which the soil gets heated up by the sun's rays in the latter county, so that while primroses, violets and daffodils appear in the west before they do in the east, the forest foliage of oak, ash, and beech bursts forth at an earlier date in the east. The rainfall of Kent is generally higher than in most other parts of the east of England, on account of the hilly nature of the country. The Dover-Folkestone coast has a somewhat bleak appearance, and in the depth of winter is liable at times to experience intensely cold easterly winds, blowing off the frozen Continent.

London and London life, as illustrating climatic influences, will be noticed in Chapters V. and VI. The rainfall of the Metropolis is 25 inches a year, and the mean temperature of the air ranges from 38° in January to 62° F. in July. The country surrounding London being varied and beautiful, and also very healthy, is well-adapted for residential purposes, so that London, being free also from the encumbrance of a ring of fortifications, is unique among the great European capitals for the great distance to which its suburban life has radiated.

The south and east quadrant of the whole country,

suffering less from the violence of wind and rain than the north and west, presents on that account alone a richer and less wild aspect; but the quieter character of the scenery is primarily due to the lower level of the land, and the newer age of the sedimentary rocks which have not been disturbed by ancient volcanic eruptions, as farther north and west in the British Islands.

These southern and eastern counties of England are the only part of the British Isles to enjoy the song of the nightingale in the month of May. Whilst cold and the comparative scarcity of tangled undergrowth would seem sufficient cause to exclude this summer migrant from Scotland and the north of England, its absence from the west of England and the south of Ireland would seem to indicate that remoteness of geographical position is a more important factor than climatic differences, since this bird is considered to reach our shores from a south-easterly direction.

Wales.—As a climatic region, Wales calls for special notice on account of the mild temperature of the coast and the cold and wet mountain climate of the interior. Among the Snowdon group of mountains is situated one of the wettest spots in the United Kingdom. The mountain scenery of Snowdonia is perhaps the most grand and rugged that exists in the United Kingdom. The close mountain valleys are not only exceedingly rainy, but are also very gloomy, being cut off from much of the direct light and heat of the sun. The shadow of the mountains is reflected to a considerable extent in the character and customs of the Welsh people. Like the other highlands of Britain, the Welsh mountains conceal uninhabited solitudes of the most eerie description, such as the fiercer moods of wind and weather alone can portray.

The East of England. — Right across the central plain, the eastern projection of England, composed of East Anglia, or the counties of Norfolk and Suffolk, forms the exact antithesis as a natural region to the westward projection of Wales. The climate is admirably adapted to wheat-growing, being drier and relatively extreme. The flat land surface is laid out in a rich combination of pasture, arable, and woodland, and typifies perhaps more than any other part of England the essential conditions of a quiet and prosperous rural life. The general moistness and equability of the English climate extend sufficiently to the eastern counties to prevent the scenery anywhere assuming the harder character of the agricultural plains on the mainland of Europe. The climate of the Dutch-like Fen Country lying inwards from the Wash, has been enormously improved by artificial drainage and reclamation of large areas of marsh land.

The North of England.—The six northern counties of England belong, strictly speaking, to the same climatic province as the southern counties of Scotland, having more in common with them than with the southern part of England.

The Pennine chain of mountains—the backbone of England and the water-parting of the north—based on limestone rocks, capped by the Millstone Grit formation, has a high rainfall, and supports only heather, coarse grass, or boggy vegetation, according to the degree of natural drainage of the soil in different parts. It is a region of wild desolation, with probably the bleakest climate in the whole of England; and along the entire length of the chain, from the Cheviots to the Peak in, Derbyshire, furious rainstorms are the rule, varied in winter by heavy snow-falls, and no visitor to the district

need be surprised to see the snow fall in May as thickly and with as much impartiality as in February. The large quantities of rain which fall over these elevated moorlands are in places collected in reservoirs, for the supply of the great industrial towns which have arisen on the coal-fields on the slopes of the chain, especially in the river-valleys of Lancashire and Yorkshire.

The northern *corner* county of the *triangle* of England (compare the other corner counties), Northumberland, suffers particularly from a bitterly cold and backward spring, following a long, dark, inclement winter, due to the northerly location, *plus* the easterly slope of the land towards the north-east winds, which prevail in March and April; but, in spite of these adverse conditions, there is some good agricultural land in the lowland part of the county near the coast, and the later summer is often mild and pleasant.

The mountainous Lake District of Cumberland and Westmorland has the distinction of containing the wettest spot in the United Kingdom, with the huge rainfall of over 200 inches a year. During rainy spells, which last frequently for many weeks in succession, a dry day is unknown, and rain falls with obstinate persistency among the Lake Country hills. The beautiful valleys (dales) of the Lake District, which radiate from the Scawfell group of mountains after the manner of the spokes of a wheel, contain pasture meadows of the most exquisite emerald hue in consequence of the rain, and some are sufficiently warm and sheltered to permit of the growth of deep woods and fine scattered trees; but once one leaves the lowlands and penetrates into the heart of the *fells* (as the hills in the north of England are termed) and explores their inmost recesses, scenes of indescribable desolation present themselves, such as

bear eloquent testimony to the severe climatic conditions of elevated land in a high latitude.

Although never much exceeding 3,000 feet in height, the lakeland fells, instead of having their slopes clothed with woods and vineyards and dotted over with cottages, as they would be in a more southern latitude, are uninhabited and uninhabitable, save only by the hardy breed of Herdwick sheep; and in the bare, black hollows of the hills, which often conceal sullen tarns, the only wood to be seen is a ragged hawthorn bush here and there, twisted into hideous proportions, the sport of wind and weather; whilst the melancholy bleating of the upland sheep, and the occasional croak of a raven, are sounds which enhance the general effect of the severe scenic character impressed indelibly upon the northern hills by angry blasts and black, rolling clouds.

The inclement climate of the north of England seems to have given rise among the hardy working-men to a curious colloquial use of the verb to *starve* which does not prevail in the milder climate of the south. In the south of England one only hears the word "starve" used in the one-sided sense of perishing of hunger and not of cold, and if a New Forest herdsman or an old Sussex hedge-clipper were to say he was starving, it would imply that he was in dire need of food. But when a north-countryman feels cold, he tells you he is "starved," irrespective of whether he is hungry or not; and it is natural that he, being exposed to much bleak weather, especially on the moors, should have retained the true Anglo-Saxon meaning of the verb "to starve," which is to perish of cold as well as hunger; whilst the south-countryman, with his shorter winter and better summer, helped, possibly, by other causes unconnected

with climate, allowed the second meaning of the word to fall into disuse. Whether the difference of climate between the north and south of England was sufficient to originate the difference of colloquial usage or only served to perpetuate the tradition, it is difficult to say, but the question is an interesting one as bearing upon the influence of climate upon local phraseology. For the industries of the north of England in relation to climatic control we must refer to Chapter VI.

Scotland.—The climate of Scotland as a whole is colder, wetter, and characterized by more sudden and violent changes of weather, than that of England. The southern counties, with their high grass-covered uplands and green-wooded lowlands are similar to, though less luxuriant than, the southern counties of England; and in the central lowlands of Scotland, a fertile soil and a climate not too hard have evoked scientific farming operations on a highly profitable scale. But we come to a very different region in the Highlands.

This elevated region, covering the bulk of northern Scotland, is believed to be one remnant, like the mountains of Norway, of an ancient plateau of great height which has been *circumdenuded*, or worn down, and carved out into deep glens and valleys by the agency of rain, streams, and ice, the more durable rocks being left as rugged mountainous masses, like Ben Nevis, 4,406 feet above the sea, the highest summit in the kingdom. The surface of the Highlands is varied by expanses of heather, bracken, exposures of naked rock, or remnants of pine forest, and shows in a culminating degree that wild moorland scenery which is so peculiarly the product of the climate of Britain on all the higher lands. The Swiss Alps, with all their overpowering grandeur, uplifted under more southern

skies, and bearing successive zones of vegetation from base to summit, show nothing in their rocky wildernesses or deserted snow-fields in any way similar to that weird, melancholy character which is born of the frowning skies and driving mists of Scotland; and it must be remembered that, while the framework of a country's scenery depends upon geological factors, the colouring effects, or "finishing touches," so to speak, are always imparted by atmospheric—*i.e.*, climatic—conditions. In the Western Highlands the storm systems of the North Atlantic low-pressure region, with their accompanying changes of wind and weather, often succeed one another with astonishing rapidity. The winds, laden with rain or sleet, howl furiously through the glens; the low driving mists course among the mountains, hiding first one rock, then another; all seems a savage chaos of intermingled rock and cloud; and dark eagle-haunted crags, which one minute show phantom-like through a rift in the storm, the next disappear from you in a shroud of mist and rain, or clenched in the teeth of a blinding swirl of sleet. Severe weather in the Highlands is often very cruel, and has a peculiar character of its own. The terrors of a Highland snowstorm are world-famed, and have been inseparably associated with those tales of bravery and romance which have done so much to cast upon Caledonia her strange glamour.

The climate of the outlying islands of Scotland—the Shetlands, Orkneys, and Hebrides—is pronouncedly maritime; and as these islands lie so far north, it is of a cold, wet, and wretched description, whilst the seasonal changes in the aspect of Nature present a neutral or colourless complexion. It not infrequently happens, however, that gloriously sunny weather favours

these islands in May, June and July, during which months there is almost perpetual daylight.

The winters of Scotland are usually open, but wet, dark, and inclement, spells of muggy warmth often alternating rapidly with periods of intense frost and deep snow. The summers are treacherous and often lacking in warmth, so that corn standing in the fields as late as November is not an uncommon sight. The early spring along the east coast is bitterly cold. The Scottish climate, although not without many advantages, is a stern one, and the raw cold and gloomy skies exert a repelling effect upon Italians and other peoples from the south of Europe. Tennyson, in a poem entitled "The Daisy," descriptive of a continental tour, wrote thus of Edinburgh:

> "And I forgot the clouded Forth,
> The gloom that saddens Heaven and Earth,
> The bitter east, misty summer,
> And grey metropolis of the North."

Ireland.—The Western Isle, being more under the influence of the Atlantic Ocean than the bulk of Britain, enjoys a somewhat higher average temperature, suffers less from extremes of summer heat and winter cold, and has a generally higher rainfall, which is heaviest round the coasts, in conformity with the vertical relief of the land (see maps). The northern half of the country is distinctly colder than the southern, but the difference is due, perhaps, less to the higher latitude than to the fact that Northern Ireland looks north-eastward, whilst the southern half of the country heads south-west, towards the particularly warm waters of this part of the Atlantic Ocean. Whilst, therefore, the climate is everywhere very humid, the atmosphere in

the bleaker north is relatively *raw*, whilst in the softer south it is of a more muggy quality.

The interior of the country is somewhat subject to sharp night-frosts in winter; and whilst a deep snow is a rarity in the south of Ireland, there are usually one or two such occurrences every year in the north. The pastures are probably no greener than in the west of England, but, owing to the more equable climate, preserve their colour better, summer and winter, than in England as a whole. Hence the name of the Emerald Isle. The *bogs* of the central plain, such as the great Bog of Allen, east of the Shannon, have arisen from the decay of oak forest through excessive wet in a country too flat for natural drainage; but, thanks to the antiseptic properties of the large quantities of tannic acid they contain, they emit no noxious exhalations, such as those of the marshy districts of Italy. In the warm west of Ireland hedges of fuchsia line the roads, and the constant moisture clothes the mountains with green bog-moss; yet the soil is barren, and the inhabitants have a hard struggle. When we come to speak of Russia, we shall see how a hot summer, despite an intensely cold winter, counts for far more agriculturally than oceanic warmth and equable temperature without dry sun-heat.

III. 5. The British Climate in Relation to Health and Disease.—The climate of Britain is salubrious, favourable to activity of mind and body, and to longevity. Whilst our climate certainly does not nurse the weak and ailing, it develops the robust, and, given a sound constitution, it is possible to maintain as high a standard of health in the United Kingdom as in any other country in the world, not even excepting the similar equable, though warmer, climate of New Zealand. The high

oceanic winds which prevail in the British Isles, often charged with *ozone*, are one of the great climatic advantages from a hygienic point of view, in so far as they scour the congested areas of the large cities, and thus keep the air purer by dispersing the obnoxious gaseous and carbonaceous impurities which arise from the consumption of coal, gas, and other products. But for the windy climate, winter fog in London, Glasgow and Manchester would be almost constant, instead of only an occasional visitor. The long, damp, and dreary winter, with the violent storms and sudden fluctuations between frost and thaw, is excessively trying to those who do not enjoy robust health, and presses heavily on the poor and destitute. Summer, on the whole, is much the healthier half of the year, the reverse being the case in warmer countries. The most dangerous months to health are February and March, especially when, as is often the case, the weather is severe. All the spring months are exceedingly treacherous, so that the old Lancashire precept not to cast a "clout" till May is out, should apply to the whole kingdom.

III. 6. The Climate and the People.—The influence of the British climate on the character, customs, and occupations of the nations will be studied in Chapters V., VI., VII., under the general subject of the control of climate upon man.

CHAPTER IV

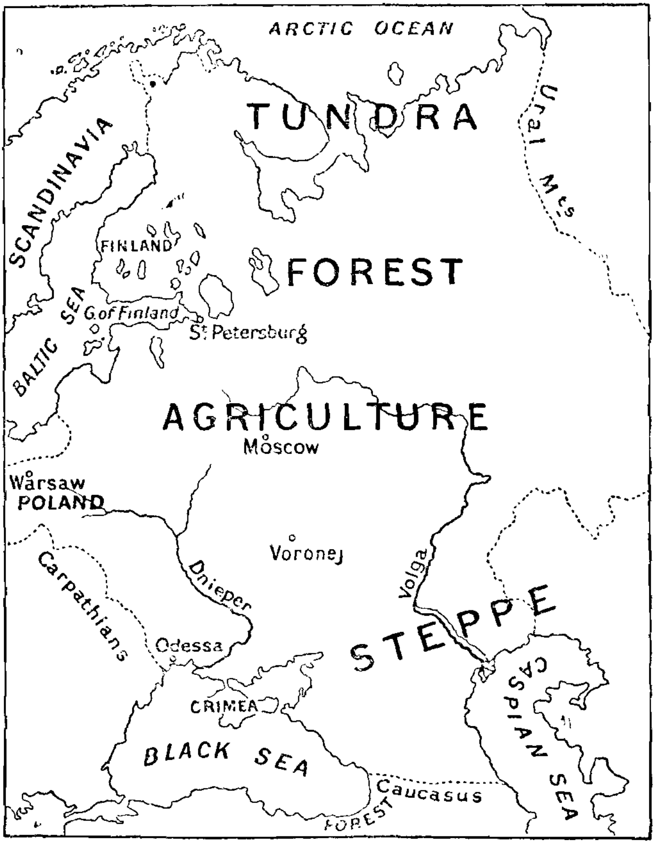
WELL-KNOWN LANDS DESCRIBED IN RELATION TO CLIMATIC CONTROL

PART II. SOME FOREIGN LANDS.

WE have now to study certain foreign lands, selected as affording typical examples of diverse climatic conditions; and as far as possible we will make it a comparative study, so as to bring out more prominently the salient features wherein other climatic regions differ from those with which we are familiar.

I. Russia.—The bulk of Russia, situated as it is between the 45th parallel and the Arctic Circle, belongs, like the British Islands, to the cool-temperate portion of the North Temperate Zone; but the climate is markedly extreme or continental instead of equable or oceanic in character. In the United Kingdom, with all our damp, changeable, and inclement weather, we can hardly imagine what it is like to live, as in Russia, under the iron rule of a severe continental climate. There the strain imposed upon the human frame by the huge difference of temperature between winter and summer, and by the rapidity with which the winter cold passes into summer heat and *vice versa* in spring and autumn, tends to cause a generally higher death-rate than prevails along the seaboard of Western

Europe, although the actually high mortality in Russian cities is due mainly to insanitary conditions. A land which extends through so many parallels



of latitude and meridians of longitude as European Russia, must possess considerable diversity of climate in different parts; and accordingly we find a number of

well-marked vegetation zones illustrative of such (Chapter II.). But before we study these regions, we must glance at a few general facts concerning the climatic conditions of European Russia as a whole.

As illustrating the continental character of the climate of Russia, due to the large area of land so near to the still larger extent of Asia, and far removed from the modifying influence of the Atlantic Ocean, the following table roughly shows how the mean temperature of the air varies from month to month at a place called Voronej, in the interior of Russia, situated approximately on the same parallel of latitude (51½° N.) as London and Valentia Island, the corresponding figures for which are being given for comparison:

	VORONEJ (Extreme Climate).	LONDON (Moderately Equable Climate).	VALENTIA (Very Equable Climate).
	° F.	° F.	° F.
January	16	38	45
February	17	39	45
March	37	41	46
April	44	47	49
May	60	53	53
June	68	59	56
July	71	62	59
August	68	61	59
September ...	57	57	57
October	44	50	52
November	34	43	48
December	22	39	45
Year	44	49	51

These figures speak for themselves; but what we have here to note is that, although in Russia a hotter summer partly compensates for the much colder winter—both the result of distance from the ocean—yet on

the balance of the whole year the climate of Britain is decidedly warmer than that of the part of Russia which lies in the same latitude. This is because in all the colder latitudes of the globe the sea, taking the average of the whole year, is warmer than the land, and therefore serves to warm the air over islands and coast regions, whereas in warmer latitudes the sea is colder than the land on the average of the year, and consequently serves to cool the air of maritime land regions. The climatic dividing line in this respect is about the 45th parallel of latitude N.

The oceanic warmth of the seaboard of Western Europe is of little avail, however, for agricultural purposes, because the summer is not hot enough, whilst Russia is one of the great granaries of the world because she enjoys a warm summer. In the eastern countries of Europe the hibernating habits of animals are more pronounced than in England or France, with their more open winters ; and large numbers of starlings, thrushes, and other birds, which could not survive the winter in lands where the soil is frozen deep under a thick canopy of snow, and where no thaw ever occurs from November to March, migrate to the west of Europe, where at least intermittent spells of open damp weather loosen the soil and allow a certain amount of food in the forms of worms, seeds, etc.

If Britain is exposed to the perils of a stormy northern ocean, Russia, on the other hand, knows the climatic terrors of an immense northern land area. With grim satisfaction the Russians attributed the retreat of the French from Moscow to the strength of her two invincible generals, January and February. The vast plains of Central Russia indeed present a weird spectacle when packs of hungry wolves travel far and

wide, and the north-east wind moans over the dreary waste of snow beneath the leaden skies of the dark days in December. The effects of the climate on the life of the Russian people will be referred to in another chapter. We must now, with the aid of the accompanying map, briefly refer to the more important climatic zones into which so large a land may be divided.

The *tundra* region (Chapter II.) occupies the far north of Russia beyond the Arctic Circle. The only inhabitants are the Lapps and Samoyedes, who wander about with reindeer herds, as in the north of Scandinavia. The reindeer is to the tundra what the camel is to the desert or the horse to the steppes.

South of the tundra a broad belt of *forest* appears, at first of pine, spruce, and other conifers, and then of the deciduous trees characteristic of the middle of the Temperate Zone. This part of Russia lies in the track of the westerly winds of the North Temperate Zone, and, although the rainfall is naturally less than in Western Europe, it is moderately abundant. Thus the covering of winter snow in this part of Russia is thick, and in summer copious thunder rains fall, so that the climate is well suited for forest growth and for agriculture in the forest clearings.

As one travels still farther south, the forests of Northern Russia give place to a large agricultural region in the west and centre of the country, with a comparatively dense population. This part of Russia contains, especially towards the south, tracts of an exceedingly fertile soil known as *black earth*, on which wheat is grown with less labour than in any other part of Europe. The snowfall in winter is here also abundant, but the wettest time, as in most parts of Russia, is in the hot summer months, when rain is

most needed. So much wheat is grown as to leave a large surplus for export to foreign countries. In Russia, as in Canada, the cold of winter, once the snow has melted, passes into the heat of summer with a rapidity which is astonishing to Englishmen. In about ten days towards the end of April the snow, which has buried everything for months, disappears, and gives place to the fresh verdure of the spring. On the other hand, the transition from summer to winter in the autumn is equally sudden. About the middle of October the icy blasts from the north already hold the land in the grip of winter, the frost intensifying as the weeks roll on till after Christmas.

There is consequently none of that tenacious lingering on of green summer foliage into November which one sees in England; but, as is the case in Canada, the autumn tints, while they do last, probably display more gorgeous colourings in the crisp atmosphere of Russia than in the damp climate of Britain.

The last great climatic region of Russia is the *steppe* in the extreme south-east. The aridity there, where there are no trees, and where grasses grow only in spring, is due essentially to the fact that it lies out of the reach of the westerly winds which bring moisture to other parts of Russia, and is exposed to easterly winds in winter from the dry interior of Asia. Although furious drifting snowstorms are frequent, there is no uniform deep snow-cover in the steppe region to protect the soil from the intense cold of the winter, and in the nearly rainless summer the fierce rays of the sun scorch up the land into something like a brown stubble-field, causing great suffering to men and animals. Hence agriculture is only carried on with difficulty by the help of irrigation; and, where this is not practicable,

the scanty inhabitants—mainly Tartars and Kalmuks—dwell in tents and roam over the arid plains with their flocks of cattle, horses and camels, as in the similar steppe region of Central Asia. The tundra and the steppe are somewhat similar in the effects of climatic control on human life; in the far north of Russia population is scanty and nomadic owing to cold; in the extreme south-east it exhibits the same character as a result of drought.

In the eastern or Asiatic portion of the Russian Empire the climatic features of the European portion —*i.e.*, low rainfall and large annual range of temperature—are intensified, and in the north-east of Siberia we find the extreme type of a continental climate, with a rainfall of about 10 inches and a mean January temperature along the 60th parallel of $-30°$ F. (30° below zero), followed by a July temperature approaching 70° F., *i.e.*, a range of 100°.

The climatic belts of European Russia are carried across Asiatic Russia without much interruption, barring the local modifications established by mountain ranges. Westward through Poland and Prussia the climate still remains extreme, but in Western Germany the modifying breath of the Atlantic holds more decided sway.

II. Italy.—The Italian peninsula affords perhaps the most appropriate example for study of one of the warm-temperate Mediterranean climates of the south of Europe, being neither so pronouncedly continental in character as that of a large portion of Spain, with her arid interior plateau, on the one hand, nor so decidedly maritime as that of Greece and the adjacent islands on the other. The chief controlling feature of the climate of Italy, as of the Mediterranean countries

in general, is a dry, scorching summer—the rainfall becoming, as a rule, smaller and smaller from north to south—and a mild, rainy winter, except on the mountains and in the far north, where the cold is severe. The dry summers are due to the fact that the N.E. Trade-wind belt shifts northward in summer with the sun, so that the bulk of Italy at that season comes under the desiccating influence of the northerly draught of air drawn into the Trade-winds, whereas in winter the northern edge of the Trade system is much farther south, leaving the westerly Anti-trade-winds to carry their Atlantic moisture to the southern countries of Europe. These conditions are reflected in the vegetation of Southern Europe, which is of a type adapted to withstand prolonged summer drought. Thus, over nearly all the lowland parts of Italy, instead of the deciduous trees of Northern Europe—oak, beech, ash, and elm—we find evergreen species, like the olive, citron, orange, and evergreen oak, or ilex. The shade temperature in summer in all the inland parts of Italy frequently approaches 100° F., and in the direct rays of the sun the heat is terrific, so that midday *siestas* in darkened rooms are the custom throughout the peninsula.

As in many warm countries, however, the variation of temperature between day and night is large, so that, as soon as the sun has set in Italy, a sensation of chilliness is often experienced even in the height of summer, and persons of rash or careless habits are liable to be "fever struck" in the cool of the evening. In addition to this the evening hours are often damp as a result of the heavy dews which are deposited with a copiousness unknown in England, where the air, though *relatively* damper, contains *absolutely* less moisture (see Chapter VIII.) than in Italy, so that less dew is

condensed on the surface of the ground by the cold of radiation at sundown. The Italian climate is salubrious on the whole, but has certain dangers: many regions, for instance, suffer in varying degrees from the curse of malaria due to the abundance of mosquito-haunted marsh land, associated with bad natural drainage and the lack of artificial means of drainage.

We must now briefly study the chief local peculiarities.

Northern Italy.—The great northern plain, including the provinces of Piedmont, Lombardy, and Venetia, drained by the River Po and its tributaries, between the Alps and the Apennines, belongs geographically to Central rather than Southern Europe, and has a somewhat extreme continental climate.

In December and January the mean temperature at Milan, in the heart of the Lombard Plain, is near the freezing-point, and this part of Italy is usually white with snow for some weeks. The cold, however, as in all the more southern countries, though severe while it lasts, is of comparatively short duration: by March the temperature is rising rapidly, May is hotter than July in England, and in July and August the mean temperature is between 75° and 80° F. The Po Valley is subject to dense fogs in later autumn. The rainfall of Northern Italy, unlike that of Southern Italy, is not mainly confined to the winter months, but is distributed throughout the year. What with the combined effects of the hot summer, with abundant rainfall, and the irrigation facilities afforded by the Po, which brings down valuable soil-fertilizing material from the Alps, the hay-meadows of the Lombard Plain yield a crop every month from May to October.

The country immediately under the Alps and sloping southward, in the neighbourhood of the Italian lakes,

Sicily and the south of the peninsula vegetation quite languishes in the long parching summer when rain rarely falls; and it has not been inaptly remarked that Sicily, far from enjoying an "eternal spring," may be said to suffer from a double winter—one rainy (the real winter), the other hot (the dry, parching summer). It must be remembered, further, that green grass such as is known in England and the north of France, is almost entirely wanting in the Mediterranean peninsula, so that the soil, baked in the dazzling radiance of the southern sun, looks characteristically bare and stony, despite the extensive vineyards, orange gardens, and other southern vegetation which, clothing the lowlands and lower slopes of the mountains, give so fertile and luxuriant a character to the scenery of Italy. The south of Italy is troubled at times with the hot sirocco wind from Africa. The high Southern Apennines are very snowy in winter, and wolves cause great loss of sheep in the vicinity of the villages.

All countries in the warm Temperate Zone which, like the Mediterranean, have a droughty summer through getting into the polar margin of the Trade-winds and a wet winter through getting into the Equatorial margin of the Westerly Anti-trades, are said to have a "Mediterranean climate." Such are California and the south-western States of the Union in the Northern Hemisphere, and parts of Southern Australia, Cape Colony, and Chile in the Southern Hemisphere.

III. Egypt.—We must picture Egypt as topographically consisting of a narrow fertile strip of Nile Valley, hemmed in on either side by desert at a considerably higher level, and expanding out into a broad fertile delta at the mouth. Egypt along the Nile border is a rich agricultural land, and though hardly any

rain falls, has an abundant water-supply, derived from the heavy summer rains, which, falling on the mountains of Abyssinia, feed the Blue Nile and cause the annual flood of the Nile in Lower Egypt. When the Nile overflows, it overspreads the valley country with a black fertilising mud, and when the floods subside, very valuable crops are raised. In the Trade-wind latitudes, where life must combat the constant menace of aridity, as of cold in the polar regions, the rivers, especially where they periodically overflow and can be used for irrigation, may determine not only the prosperity but the very existence of a nation. Thence it is not surprising that the Egyptians early regarded the Nile with a kind of veneration, depending on "Father Nile" for the fruitfulness of their land. The Nile, in fact, is Egypt, or Egypt is the Nile, the one being unthinkable without the other.

At Assuan, about the middle of Egypt, a great dam has been constructed across the river, by which the flow of water down to Lower Egypt may be stored in flood-time, and kept in reserve for the early part of the year—*i.e.*, the period of low-level of the Nile, when water is badly needed for the valuable cotton crop. No river in the world is so much under the control of engineering work as the Nile, and with the aid of an ingenious and elaborate system of irrigation a far greater area of land can benefit from the annual flood than was formerly the case.

The extreme north of Egypt just comes within a winter-rain belt. To the south of Egypt in the Sudán, where summer rains occur, the desert gradually passes into savana. At Cairo, the capital, about 3 inches of rain falls a year; the summer is fiercely hot, but the extremely dry atmosphere permits such

rapid loss of heat that the winter nights are often decidedly cool, and thin ice on shallow water is by no means so rare a phenomenon in the early hours of the morning in December or January as one would think.

Having spoken of *Egypt of the Nile* and of the way she utilises a transported, in lieu of an actual, rainfall, it is now time to study *Egypt of the Desert*, than which no part of the earth's surface more clearly exhibits the powerful effects of climatic control. As we saw in Chapter II., Egypt, with the Sahara on the west and Arabia across the Red Sea on the east, lies within an enormous width of desert area, everywhere produced by analogous climatic conditions. In addition to the perpetual drought upon which the very existence of the desert depends, another prominent feature of the climate of Egypt, itself due to the dry, cloudless atmosphere (see Chapter I., section ix.), is the great range of temperature between day and night; and this has the effect of splitting up the rock surface of the Libyan Desert in a most remarkable manner. Once the rock surfaces have, in course of time, been split and loosened into powdery fragments by the alternation of intense heating by day and rapid cooling after sundown, the wind soon takes up the work of further disintegration. Great dunes of sand move across the face of the desert, sometimes encroaching upon the green oases where the date-palm grows, and burning sandstorms are a source of discomfort and danger to camel-men traversing the desert.

Sand, in fact, as a natural element, is in the Trade latitudes what snow is in the polar, though one is derived from the decomposition of rocks and the other from precipitation out of the atmosphere. In dry regions wind-erosion is considered to play an extremely

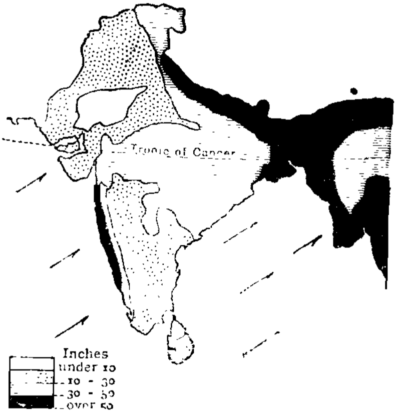
important part in moulding the configuration of a land surface; and where there is a deposit of loose sand, the sand-laden wind, acting mechanically, is a very potent instrument in undercutting rock masses, scoring their surfaces, and corroding, as in Egypt, the ancient temples and other monuments of the past. Captain Lyons has recently shown that the ancient Egyptian custom of mummifying the dead was probably connected with the very dry climate.

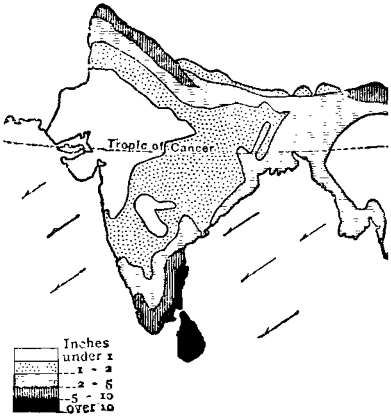
The simple climatic régime under which Egypt lies—its monotonously clear skies—whilst highly unfavourable to the study of meteorology, is well calculated to awaken a deep interest in the science of astronomy, so that it is not surprising that the early Egyptians should have been such famous astronomers, like the Babylonians in a similar climate farther east. The very flag of Egypt and of the *rainless Mohammedan* countries generally (Chapter VII.), bearing the star and crescent moon, could hardly have figured in cloudy latitudes where the heavenly bodies are more often than not concealed from view, instead of being ever-present phenomena of Nature.

Over the sea the Trade-winds which, in the days when the art of sailing was imperfectly developed, were so invaluable to vessels, determining, in fact, the great sailing routes round the globe, also bring rainless weather; but the great reservoir of water over which they blow, steaming beneath the tropical or subtropical sun, causes the sky to be flecked over with small detached cumulus clouds, sailing with the wind, instead of remaining cloudless, as over the deserts.

IV. India.—India, the great British possession of the East, has a hot climate, and it typifies a special set of atmospheric conditions, dependent upon the seasonal

alteration of the main wind currents, known as the *monsoon.* In Chapter II., section v., we saw in general terms what the monsoon wind is, and how it is set up; and





now we must study the main climatic effects of a great densely-peopled monsoon land, sweltering beneath the vertical sun of the tropics. But in order to appreciate

more fully how the rain-bearing monsoon currents in India are established, we must briefly study the temperature conditions of the country as a whole in winter and summer.

The mean temperature of the air, averaging about 80° F., ranges from 70° F. in winter to 90° F. in summer.

During the colder months the land surface of India remains sufficiently cool not to disturb or interfere with the flow of the North-East Trade-wind, with dry weather and clear skies, which, as we have already seen, forms the normal circulation of the atmosphere in the region just north of the Equator. During March and April the heat is greatly intensified, and in May it reaches a climax. Now, the fact of May—*i.e.*, a month before the sun has reached its greatest northerly declination—being generally the hottest month of the year in India is a very crucial point in connection with the climatic dispensation of India. In the ordinary course of events the next two or three months should be hotter still, and the conditions would be such as to convert the land into a "fiery furnace" in which human life would be wellnigh insupportable. But just about midsummer the heat has already become so intense as to bring about its own abatement, for the vast superheated land mass of India, assisted also by the heated summer condition of Central Asia, in virtue of the expanded air and consequently lowered atmospheric pressure over it, begins to suck in the nearest air current dynamically available. This is supplied by the South-East Tradewind of the Southern Hemisphere, which is thus drawn across the Equator, though not as a continuous current, and sucked in over the Indian Peninsula as the *South-West Monsoon*.

Charged with the moisture of the steaming Indian Ocean, and sharing in the general upward movement of the heated air, the South-West Monsoon rolls in great clouds, cutting off the sun's rays and lowering the temperature somewhat; and in a series of appalling thunderstorms the rains burst in a veritable deluge over a large part of India. Where, as along the western Ghats, the Himalayas and the Khasia Hills the monsoon meets high land at right angles, thereby being forced upwards and chilled both by expansion, and in the case of the Himalayas by the cold of the mountains themselves, the rainfall is enormously increased over what falls in the plains, and at Cherrapungi, among the Khasia Hills of Assam—the wettest spot on the globe—some 500 inches of rain fall during the wet season.

Once the monsoon has burst, the flooded country is transformed. The parched-up soil suddenly assumes the green garb of spring; drooping plants revive; trees, some of which have been bared during the long drought, don fresh leaves, and the tropical fecundity of insect life attains during the damp heat to a degree which is not only formidable, but positively revolting. Thus do the annual monsoon rains convert India into a fertile land, able to support an enormous native population. The damp, enervating heat of July, August, and September, though less intense, is, probably on the other hand, more unhealthy to the people than the dry, more bracing heat of April, May, and June.

It is now time to study the broad local peculiarities of the country, since not all the area of India comes under the influence of these rains. The maps on p. 83 show broadly those parts of India which benefit from the rain of the South-West Monsoon and of the North-

East Trade. A considerable area in the north-west of India is nearly rainless, and there is situated the desert of Sind, one of the hottest spots on earth in summer, with the maximum shade temperature in May sometimes reaching 125° F.; but, like a true desert land, the temperature on December nights occasionally falls several degrees below freezing. Another notable feature about the rainfall of India is the winter rain on the Madras coast brought by the North-East Trade. We have learned that the Trades are dry and desert-forming. This, however, only holds good provided no mountain barrier obstructs their path. The North-East Trade holds, blowing over the Bay of Bengal, much water-vapour in the late autumn or early winter, and when it is deflected upward over the Eastern Ghats along the south-east coast, a considerable amount of rain is condensed in October, November and December. The amount, however, cannot compare with the summer rains of the monsoon, and as it frequently all comes down in one or two heavy downpours, the rain in this part of India is collected and stored in tanks by tea-planters and others. In Chapter II. we saw how the mountain barrier of Eastern Australia and Eastern South Africa condenses the moisture of the South-East Trade-wind in the same way.

A few words now concerning the monsoon vegetation. The *monsoon* forest differs from the *Equatorial* forest in this important respect—that the trees composing it shed their leaves in the prolonged dry season, whereas in the rain forest of the Equatorial region, with no pronounced dry season, they are evergreen. The trees of the Indian monsoon forest are tall, and chief among them are the teak and sal. Bamboos are plentiful almost everywhere. The combination of plants composing

the monsoon forest, however, has a somewhat restricted range in India, and wherever, as on the higher levels of the mountains, the rains are sufficiently prolonged, this type of vegetation quickly passes into rain-forest, about which we shall speak under *Brazil*. In the well-irrigated plain of the Ganges, with a good summer rainfall, a succession of crops, such as rice, maize and wheat, is raised in a year, and silk-worms are reared.

The tableland of the Deccan stretches away eastward from the top of the Western Ghats, and in place of the luxuriant forests of the western side of these mountains, where tigers prowl and savage men dwell, a dry tract of semi-desert country lies in the rain-shadow of the Ghats, the rainfall being not only scanty, but also very uncertain, with the result that this part of India is liable to famine.

The strength of the South-West Monsoon seems to depend somewhat on the snowfall of the Himalayas. When the latter is heavier than usual, the chilling effect lessens the draught of the warm south-westerly air-current from the Indian Ocean, and conversely.

The huge wall of the snow-clad Himalayas effectively cuts off the moisture of the South-West Monsoon from the inhospitable tableland of Tibet to the north, but eastward of Tibet, China proper, another densely-peopled agricultural land, owes her prosperity to abundant monsoon rains, drawn from the Pacific Ocean into the heated land in summer.

Similarly, in the southern summer the heated land of Australia causes a similar monsoon development to that of India in the northern summer, the North-East Trade-wind being drawn across the Equator and converted into a North-West Monsoon supplying Northern Australia with an abundant rainfall. Hence we

sometimes speak of the Indo-Australian monsoon system.

V. Brazil.—We have now to study a typical Equatorial climate, and for the purpose will consider the great Amazon basin of Brazil, between the highlands of Guiana on the north, of Brazil on the south, and the Andès on the west. So vast an area as Brazil must necessarily contain much diversity of climate, from the humid northern plains of the Amazon on the one hand to the bleaker highlands on the extreme southern projection of the Republic, where frost and snow are not unknown, on the other.

The Amazon basin experiences the constant rains of the Equatorial (doldrum) belt, giving rise in the absence of any prolonged dry season to dense rain forest (*selvas*). The southern part of Brazil falls under the influence of the winds of the South-East Trade system. Yet there is no sterile desert region. The reason is partly that the Trade has traversed a wide expanse of tropical sea, and thereby become charged with moisture, and partly (and, indeed, primarily) the fact that the configuration of the land surface of Brazil is favourable for extracting an abundant and fairly well distributed rainfall from any winds which blow over it. The highland country of South-Eastern Brazil consists of alternate ridges and valleys, extending in a broad tableland far into the interior of the country; and the oceanic winds, rising gently over this undulating tract of moderate elevation precipitate their moisture with sufficient copiousness to favour luxuriant forest growth near the Atlantic coast. This passes into savana (campos), where the rainfall tails off behind the coastal mountains, farther west, Farther west again, where the South-East Trade has to climb up the mighty barrier of the Andes, a very heavy

rainfall is, as we have already seen, condensed on their eastern slopes, again nourishing forest growth. It is important to note that, while the northern or tropical Andes get rain on the eastern slope from the South-East Trade, the extreme southern or temperate part of the chain receives rain on the western slopes from the westerly winds of the South Temperate Zone.

The evergreen rain forests of Equatorial Brazil, revelling in the damp heat, afford a paradise for the study of natural history and support a highly characteristic fauna and flora, many forms of which show marked adaptations for the climbing or aquatic habits, which dense vegetation in a land of superabundant water necessitate. The monkeys of the Amazon forests have a prehensile tail, serving the purpose of a fifth hand. In the rainy season the Amazon and its tributaries overflow to a great distance from their banks, so that the forests and mangrove swamps appear to be growing in the water, and in consequence of the universal flood the wild tribes of Indians frequently erect structures raised on piles and travel about in boats.

The economic produce of the Amazon forest (Chapter II., section iii.), what with rubber, rose and satin woods, drugs, etc., is very great, but for this subject one must refer to treatises on commercial geography. The dense overcrowded tropical forest—the top and bottom of which almost present two distinct scenic worlds, one of light, the other of gloom—is thus well described by Dr. H. R. Mill: "The *Selvas* of the Amazons, the darkest forests of the Congo and its tributaries, the forests of the Western Ghats of India, of the west coast of the Malay Peninsula, and of the islands of the Malay Archipelago, vie with each as types of the utmost wealth of vegetation. Soft, leafy

canopies, borne by lofty evergreen trees, meet and intercept the light, so that no grass can grow in the dark depths of the woods; but climbing and twining plants innumerable, with stems like ropes or cables, force their way up on the trunks of their stouter rivals, and push on, to expand their crown of leaves in the sunlight. The decaying vegetation below supplies abundant nourishment for pale-coloured parasitic plants, which, deprived of sunlight, have lost their chlorophyll and the power to manufacture food, and therefore live on their fellows."

Darwin remarked, in proof of the quality of tropical rain, how in a sudden downpour in Brazil the water streamed down the tree-trunks, and that an ordinary English shower would be evaporated or absorbed long before it could penetrate to the bottom of a Brazilian forest. In the open savana region of Brazil there occur in moist soil along river-banks groups of perhaps the most elegant and beautiful of tropical palms—the burity palm—forming open, well-lighted forest with a rich ground flora. Far up on the eastern face of the Andes, amid the gathering grounds of the Amazon, is one of the cloudiest regions in the world, where even the vertical sun of the tropics but seldom succeeds in dissipating the dense humid vapours, discharging their load of snow on the higher levels and their torrents of rain lower down.

To contemplate the vast volume of water ceaselessly being borne to ocean by the mightiest river on earth makes one realize on what a gigantic scale the process of distillation is ever progressing over the hotter parts of the globe—a natural process, wherein the ocean heated by the sun, represents the boiler, and the mountains, chilled by the cold of space, the condenser.

VI. Greenland.—In Greenland we find the physical conditions of a frigid land. The bulk of the area is buried under a shield-shaped ice-cap some thousands of feet thick, and, if we except that of the South Polar Continent, the largest and thickest in the world. The existence of a vast sheet of inland ice like this depends on two factors—(1) cold sufficiently intense and prolonged to cause snow to accumulate during the year faster than it can disappear in the short summer; (2) an abundant precipitation in the form of snow. This last is very important, for in the extreme north of Greenland, where the snowfall is scanty, there is no continuous ice-sheet, whereas in the south, where the damp winds strike high land, the snowfall is very deep and uniformly spread. Below the ice-cap, which in parts has probably a thickness of as much as 6,000 feet, lies a high mountainous land formation, composed chiefly of gneissic, basaltic, or other ancient rocks, whose high peaks and deep depressions are outlined in the ice-cover.

The East Greenland marine current, strengthened by the prevalence of north-easterly winds, makes the east coast of the island colder and more difficult of access than the western. The Greenland summer is raw and inclement, the mean temperature of the month of July at sea-level being well under 50° F.—the minimum for tree-life—even in the extreme south. As in other highly mountainous countries, a local wind dynamically heated and dried by descent into the deep valleys is known in Greenland, which has the effect of melting the snow. In Switzerland this "föhn" wind, as it is called, is so hot and dry that it melts more snow in the valleys in the course of a single night than the sun can in the course of a fortnight.

It would be correct, geologically speaking, to say that the surface rock of Greenland is ice, and it is fascinating to see how much like an ordinary rock-surface, as regards landscape sculpture, ice will behave. The soft mantle of freshly-fallen snow gradually compresses the old snow beneath it into solid ice, increasing the thickness of the ice-cap, which has thus, after the lapse of ages, become thousands of feet thick. The great vertical pressure to which the inland ice is subjected, has the effect of forcing out laterally into the sea streams of ice, called glaciers, which thus drain the land. Some of the Greenland glaciers move as much as 60 feet in a day. The great Humboldt Glacier moves down its gorge straight into the sea, where it terminates in an ice cliff sixty miles wide and 300 feet high. The glaciers push their way into the sea along the bed of the ocean, till the water-pressure, acting upwards, imposes such a strain on the ice-mass that huge masses of ice are snapped off, and, being specifically lighter than water, spring to the surface as icebergs, one-ninth only of the volume being above water. These bergs, travelling southwards in the Arctic current, refrigerate the atmosphere around them, and are the cause of Labrador's inhospitable wastes in the same latitude as Britain, while even as far south as Newfoundland they occasion inclement conditions, with dense raw fogs along the coasts where the icy waters mingle with the warm Gulf Stream.

In summer the surface thawing makes ponds here and there on the Greenland ice-sheet, their site being often marked by fog banks; and rills issue from these ponds, and disappear through cracks and fissures in the ice, joining the glaciers below, and thus assisting them in the drainage of the land. This emphasises what we

remarked above—that ice acts analogously to land-rock towards liquid water and other landscape elements.

In the south of Greenland, which extends in Cape Farewell as far south as the 60th parallel, low woods of stunted birch and willow grow in sheltered localities. The low ground of the north of Greenland above the 80th parallel bears vegetation enough to support herds of musk-oxen and numbers of Arctic hares (*white*, to match their surroundings), both animals appearing to wander farther north than the reindeer. The few people of Greenland are of the Eskimo stock. They live during the winter in snug snow huts resembling beehives, and seek the means of subsistence in the sea, especially along the east coast.

Iceland, to the east of Greenland, warmed by the Gulf Drift, has no ice-cap, though it lies farther north than the south of Greenland. Its climate is more of the British and Norwegian stamp—wet, stormy, and raw; but, needless to say, all the worst features of the British climate prevail in Iceland in an intensified form, whilst there are few of the good features which favour our more southern land.

CHAPTER V

THE INFLUENCE OF CLIMATE UPON MAN

PART I. INDOOR LIFE.

Preliminary.—The life of man, which is subject as rigidly to climatic control as the land on which he lives, is the next subject to claim our attention, and for the purpose of convenience we may divide the subject into Indoor Life and Outdoor Life, although, of course, some aspects of life cannot logically be relegated exclusively either to the one heading or the other.

I. Building Material and Plan of House.—Primitive peoples low down in the ladder of civilisation, whether of the Arctic region, the tropics, the desert, the steppe or the high mountains, have to build their rude habitations of whatever material Nature locally supplies. Simple structures of this sort, demonstrating climatic control more obviously, though not perhaps more surely, than the refined and complex houses of civilised nations, we will speak of first. The Eskimo in the far north, living in a world of snow, finds that material the most suitable for making his house, and so he collects some old compact snow, fashions it into a sort of beehive-shaped hut, with a low entrance shut by a door of ice or snow, and having a clear sheet of ice in the wall

to serve as a window, and calls it an *igloo*. In this, furnished with a lamp for lighting, heating and cooking purposes, some blubber to supply oil and fuel, dried moss to furnish a wick, and a dish to contain melted ice for drinking, he lives through the long polar winter, and manages to make himself snug. Snow, it must be remembered, is a bad conductor of heat, so that, although a cold substance, it can only steal heat with comparative slowness when in contact with the human body or any other hotter subject; and when it is present in sufficient quantity to deeply bury or environ an object, the heat is prevented from escaping, and the object is kept warmer than it would be if left exposed to the frosty air. Hence the Eskimo find their snow-huts warm and comfortable. During the summer, when his *igloo* is liable to become damp because the snow superficially melts, the Eskimo becomes more nomadic in habit, and travels about with tents made up of skins in search of hunting and fishing grounds.

The native of the tropical forest, on the other hand, makes his hut of bamboo, palm and cocoa-nut leaves, sugar-cane and grass. During the floods of the rainy season, and in the region of mangrove swamps, the natives of Borneo and Brazil erect structures supported on piles, and travel about in boats. Permanent dwellings in tropical cities are best built of stone, since wood is liable to decomposition through damp and to destruction by termites and various other insects.

The few inhabitants of the sand deserts, as of the snow, are perforce more or less nomadic in habit on account of the scarcity of food. In the tropical deserts the more permanent dwellings are built of stone or adobe, and have flat roofs on which the people sleep at night; but, when wandering about, they make encamp-

When an Englishman or a German leaves his northern home to visit Southern Europe, one of the first things which strikes him about the inside of houses is the scarcity of carpets and the prevalence of bare stone or wooden floors, protection against the heat of summer being in the Mediterranean countries of more importance than against the cold of winter. In the extreme continental climate of Northern Italy (Chapter IV.) the larger houses often have an airy lower ground story of bare stone floors for summer occupation and a well-carpeted, warmly-furnished upper story for winter use, the latter affording a somewhat remarkable instance of the hibernating habit in civilised human life. Northern Italy, it will be remembered, has the climatic conditions of Central rather than Southern Europe.

The interior of a well-appointed English house is a model of well-studied comfort, with all kinds of devices for banishing the cold and damp outside, because in England the cold of winter is longer and of more importance than the heat of summer, and so we find thick, warm carpets, curtains slung before the windows, and other ingenuities for snug habitation. In England, too, we covet, as a rule, all the sunshine we can get, so window-blinds are sufficient; but in the dazzling radiance of an Italian summer, the question of keeping the rooms dark and cool for the afternoon *siesta* being of supreme importance, thick, double shutters, white inside and green outside, furnish the window-frames of all the houses. In the damp, Equatorial latitudes, where the atmosphere reeks with moisture in the wet season, it is practically impossible to preserve wooden furniture from mildew due to the wet. Mosquito climates render muslin nets around beds imperative for undisturbed sleep. In the tropical island of Mauritius, where

hurricanes of great violence are liable to occur, every house is furnished with strong iron "hurricane bars," to secure the doors and windows on the approach of a storm.

The different systems of heating and cooling house-rooms often exemplify climatic influences in a peculiarly subtle manner. Take, for instance, the method of heating in general use on the Continental mainland of Europe in contrast with that in vogue in Britain. On the Continent the cold in winter is severe, but it is usually of dry, bracing quality; and the large closed metal or brick stoves projecting into the middle of the room, and terminating in a long flue commonly used, are designed to keep the houses very warm and armed against hard frost. But the Englishman, and, above all, the Scotsman, although liable from time to time to endure spells of frost as intense as any to be experienced in Continental Europe, has more usually to contend against another formidable enemy of the northern winter —namely, a damp, dismal kind of cold, which is always the alternative to hard, dry frost in a high latitude, so that it is not surprising to discover his system of heating his house specially directed against this prevalent depressing condition of the atmosphere.

Hence, in the British Isles the system of heating universally employed is the open-grate fire, which although often inadequate for the proper heating of rooms, since so much heat escapes up the chimney, is pre-eminently cheering; and there can be but little doubt that the depressing character of the British winter has exercised this control over the firesides of the British people. In Canada, again, where the cold, being usually dry, calm, and bright, is much more agreeable than the damp, gloomy, windy cold

of England, notwithstanding the much higher temperature, hot-water heating replaces fire heating to a considerable extent. In some parts of Southern Europe, as in the south of Portugal, the climate is so mild that most of the houses are not fitted with fireplaces at all. In Equatorial Africa, however, where the damp, relaxing heat (damp heat being much more injurious to health than damp cold, and just as unpleasant) so weakens the vitality of the negroes as to render them very susceptible to the nocturnal cooling of the atmosphere, many tribes sleep on clay banks heated by fires, although the temperature at night rarely falls below 70° F.

Just as in cold and cool-temperature latitudes the chief problem is how to keep the house warm enough for health and comfort, so in warm-temperate and hot latitudes it becomes how to keep it cool.

Refrigerating apparatus and artificial ice-producing plants are employed in hot countries, as well as various fan contrivances, like the punka in India, for creating artificial currents of air in the rooms, which promote evaporation from the surface of the skin, thereby inducing a sensation of coolness. At Haidarabad, in the North-West of India, wind-sails are appended to the outside of the houses, and these, catching the wind, are very effective aids in ventilating their interior.

In Australian houses a characteristic item of furniture is a canvas bag for the purpose of cooling drinking water. The principle of it is this: the water inside the bag, in oozing through the canvas, is evaporated with such rapidity in the dry heat of Australia that a considerable reduction in the temperature of the water takes place. The canvas bag would be useless in the *damp* heat near the Equator.

vegetable products (particularly nutritious or juicy fruits), such as the banana, coco-nut, breadfruit, rice, yams, sago, sugar, etc., and in the desert oases the date. Animal food is little used by tropical natives, partly because it is more troublesome to hunt and prepare than the lavish abundance of vegetable food around them, and partly through disinclination for it. Some authorities maintain that the anæmic condition of tropical tribes is due to the lack of meat in their diet; but this only begs the question whether, in climatic conditions which do not seem to demand or even permit the consumption of much animal food, results detrimental to health would not ensure in the very attempt on the part of the natives to raise their vitality in this way. The fault is in the climate, for the fact is that a tropical, but especially an Equatorial climate, is the mortal enemy of man. The polar climate may forbid human life altogether; the Equatorial climate permits it, but enacts a heavy penalty for the concession. When white people go to tropical lands at the call of duty, they have to take great care to adjust their diet and general habits of life to the climate. The climate of India, for example, may make very short work of an Englishman if he attempts to preserve home habits.

Not only over the nature of food does climate exercise control, but also upon its preservation. It is not heat alone which favours the putrefaction of food, but damp added to the heat. Hence food will not keep in the Equatorial belt or in damp summer weather in the Temperate Zones. In the damp Equatorial latitudes ordinary table-salt, which contains chloride of magnesium as an impurity, deliquesces so rapidly that another kind of salt of a different chemical nature has to be specially prepared for table use. The Boers of

the high South African veldt are said to preserve food by exposing it outdoors all night in the dry air. In the polar regions food, of course, keeps well, but it also does in the hot tropical deserts, on account of the extreme dryness of the atmosphere. Ice obtained naturally or artificially produced is largely employed for the preservation of food in tropical lands and in temperate countries during the summer. In India there is a great demand for refrigerator railway carts for the transport of milk.

The hot city of Mexico is fortunate in having the natural refrigerators of snowy mountains in its neighbourhood, and large quantities of ice and snow are gathered on the mountains and brought down to the hot plains below. In Palestine snow from the mountain is brought to lower levels, and preserved in wool-lined pits till required.

The subject of dress and clothing will be more appropriately dealt with in the next chapter on Outdoor Life. Meanwhile, we need only note that little or no warm clothing is needed in tropical latitudes. European residents in the tropics, however, find light woollen clothing useful for night wear as a precaution against chill.

One of the gravest dangers to health in the tropics is the risk of taking chill. This apparent paradox is explained by the fact that the excessive and persistent damp heat, with no cold winter season, so lowers the vitality of the body that it becomes morbidly sensitive to the drop of temperature which takes place in the evening or during rains, although, as we have observed elsewhere, the air temperature scarcely ever on the Equator falls below the high level of 70° F.

Climate sometimes influences the occupations of in-

door life more or less obviously, but less markedly than those of outdoor life. Thus, singers know how different climatic conditions or different weather conditions in the same climate affect the quality of the voice. So dry is the atmosphere of a Canadian winter that many effects of animal electricity are said to be apparent, which are quite impossible in the damp English winter, where the superficial deposit of moisture coating all objects conducts electricity too rapidly into the ground. Persons, for example, combing their hair in a darkened room in Canada see and hear electrical discharges; and a favourite game is to electrify a person by friction, insulate him on a glass-legged stool, and make him light the gas by means of an electric spark from his finger-tip.

When one surveys a number of written proverbs in different languages, climatic influence may often be detected.

Among the most obvious examples we have the English maxim: *Make hay whilst the sun shines.* This, of course, could only have arisen in a land where the summer skies are fickle and changeful.

Again, the proverb: *A man without a wife is like a man without a fur bonnet in winter*, shows its Russian origin in pointing to the necessity of fur head-gear in the Russian winter.

Finally, the Turkish proverb, *Death is a black camel which kneels at every man's gate*, shows climatic control indirectly, in referring to the camel as the characteristic quadruped of the desert climates of Northern Africa and South-Western Asia, but in its fierce imaginative colouring and vivid portrayal of a solemn reality it unquestionably betrays the exciting effect of the Southern sun.

CHAPTER VI

THE INFLUENCE OF CLIMATE UPON MAN

PART II. OUTDOOR LIFE.

I. Scenic.—We have seen how all over the world, in climates hot and cold, wet and dry, man needs shelter from the atmospheric elements, and that the habitable structures which he accordingly raises vary in type according to his degree of civilisation and to his general geographical environment. It is, of course, obvious that men can pass, on the whole, a larger proportion of their time out in the open air, in warm, especially dry, countries, than in cold, especially damp, countries; and it would be going over old ground to discuss these broad general differences. But if we take Europe again, as we did in the last chapter, as our geographic unit, and confine ourselves more especially to the differences apparent between the northern and southern countries of that continent, we observe, as usual, highly interesting results of climatic control. Now, in the warm countries washed by the Mediterranean Sea, where the languor of summer life is such as Northern Europeans can never realise till they have visited those countries, the cities present examples of idle, and frequently demoralised, street-life such as the climate of Northern and Central Europe would absolutely

Frith

DATE-PALMS.

A scene at Elche, on the south-east coast of Spain, the only part of Europe where the climate permits the date-palm of Northern Africa to flourish.

forbid. In Neapolitan districts, for example, the peasant women dress in gorgeous colours, the men of all classes are much given to lounging about in the open, and the poorer classes frequently work at their various handicrafts outside their doors or actually in the street, the lively temperament of the Southern Italians being highly conducive to customs of this sort. In these countries, however, a bleak day is wont to produce an unaccustomed deserted appearance, keeping people indoors, as they are less fond of facing a cruel northerly wind for the mere pleasure of being in the open air than we English people are. From this, however, it must not be supposed that either the Italians or Spaniards are an enfeebled race. On the contrary, the wonderful powers of endurance found among the lower classes of Italians, and the small amount of food on which they can subsist, not only in their own, but also in colder foreign countries as well, are well known. It would seem, therefore, that the warm-temperate countries of Southern Europe, not situated too far south to escape the tonic effect of a cold though short winter, may possibly enjoy a climate more conducive to strong vitality than, *e.g.*, a very cold, nearly arctic land like Scandinavia in the far north of Europe.

But it is quite clear that if Britons, Germans, and Scandinavians were to stay at home in inclement weather, they would not get out much at all for a large part of the year, and so we find climatic control manifested in this case, not in keeping people indoors, but in the somewhat unexpected manner of forcing them out in the pursuit of healthy bodily exercise. In other words, the Northern nations adopt hardy habits because their climate makes them do so.

The Englishman spends much leisure time working

in his garden or away from home in some form of manly outdoor exercise; and it goes without saying which is the healthier for mind and body, the secluded home-life, varied by outdoor exercise, of the Englishman, or the lounging street-life of the Italian. Moreover, the English climate, with usual absence of dangerous extremes of heat and cold, is eminently favourable to outdoor exercise in some form or another; and the monarch who said that more time could be spent in the open air in England than in any other country in the world was not far wrong after all.

Extreme features in any particular climate are often reflected in the style of architecture developed in towns. In the brilliant Mediterranean countries houses are commonly white and fitted with outside window-shutters, as mentioned in the last chapter, whilst the dryness of the air and rapidity with which rain evaporates in those countries permits flat roofs to be more generally adopted than in the damper northern countries.

An excessive regular winter-snowfall in Montreal has caused the roofs in that city to be "steep-pitched"—so designed that accumulations of snow are shot out by their own weight in such a way as to fall clear of the pedestrian's pavement, and alight by the side of the road in the gutter. In London, on the other hand, although inconvenience sometimes results from the falling of snow from roofs in quiet suburban roads, the snowfall is not great enough nor regular enough to demand such an architectural modification.

In dress, the scenic element is climatically influenced both as regards colour and material. The hot sunshine of low latitudes calls forth gay-coloured dresses among people of all classes, and both men and women use wide-brimmed straw hats and parasols.

In higher latitudes, sunshades are only used in summer by women, while sombre-coloured dresses keep tone with cold grey skies for the major portion of the year.

The relative merits of fur and wool for keeping out the cold in higher latitudes is sometimes hotly contested even for use on Polar expeditions. No doubt both these animal products are valuable for the purpose, but the balance of evidence seems to be in favour of fur clothing, although it is possibly less hygienic than thick woollen fabrics, affording the more effective protection against intense cold. In the Arctic regions, where fur-bearing animals abound, the Eskimo of necessity clothes himself with that material from head to foot. Fur cloaks and fur bonnets impart a distinctive scenic character to St. Petersburg and Moscow in winter. In London women wear furs rather largely in winter, and some men also wear fur-lined overcoats, whilst woollen or fur-lined gloves are in general use.

The Scottish Highlanders' plaids are proof against any cold, and it must be remembered that the inhabitants of Northern Britain have at times to face exposure to some of the roughest weather that occurs on the earth's surface. We saw in the last chapter why light woollen clothing is useful for night-wear in tropical countries. The umbrella is now a familiar object in all civilised countries, hot or cold, which get rain. In the British Isles, so unstable is the weather that it is only on about one day in every twenty, taken at random, that one may feel fairly certain, on leaving home in the morning, that it will not rain during the day; and hence, open or closed, the umbrella is the constant companion of the average London pedestrian,

and, indeed, forms an important part of his outdoor equipment.

Climates of an extreme type in one direction or another may give rise to special modes of locomotion: thus, the Eskimos traverse the frozen snow in dog or reindeer sledge; Equatorial natives move about the flooded country so much in boats that certain tribes scarcely know how to walk; whilst in those temperate countries which, like Canada, Sweden, Russia, and Eastern Prussia, experience a continental winter, the sleigh replaces the wheeled vehicle of normal conditions. There is, besides temperature, humidity, wind and sunshine, another climatic element which profoundly modifies the habits of people with respect to indoor and outdoor life, and that is the varying length of the day in summer and winter in different latitudes. In low latitudes, say between 45° N. and S. of the Equator, there is missing that great contrast between the length of the day in June and December that is so striking in high latitudes, *i.e.*, north and south of these parallels respectively.

The Greeks and Egyptians, not knowing either the long summer day or the equally long winter night in the sense that we North Europeans know it, vary their habits comparatively little with the seasons. Imagine the stupendous contrasts to which we British people, living on the polar side of the forty-fifth parallel, are half-yearly subjected in our scenic environment, as we are swung between the brilliant sunlight of the glorious month of June and the half-daylight of dark December.

At midsummer, when the sun rises well in the north-east between three and four in the morning, blazes high up in the noon-day sky, sets well in the north-west between eight and nine in the evening, and sinks but a

ESKIMOS WITH SNOW-HUTS AND ARCTIC DOGS.

which is, however, always stopped when the ground is frozen hard.

The greater duration of the cold of winter than the heat of summer in the latitude of England—the fact that there are eight cold months with a mean air temperature below 55° F., which is usually regarded as the temperate level, and only four months with the mean temperature above that level—has a very good practical illustration in the relative lengths of the football and cricket seasons. The national winter game lasts officially through the eight months, September to April; the national summer game through the four months, May to August. It is true that the mean or average temperature of the air is higher in September than in May, being a little above 55° in the south of England in September and a little below it in May, so that on this score September should be officially a cricket month and May a football month.

But although the soil and atmosphere remain cool in early summer, for reasons which are discussed in the first chapter, the days in May are very long and the sun very powerful, having nearly reached its midsummer altitude, so that, taking it all round, May is more truly a summer month and more suitable for cricket than September. In Australia and South Africa the cricket season is, or ought to be, twice as long as in England, whilst play is not usually commenced with the prospect of being stopped by rain, as at home.

III. Farming, Engineering, Commerce.—Of all branches of outdoor industry, farming is the one over which climatic variations, and relatively slight variations too, exercise the most powerful control. This fact has been abundantly brought home to us in previous chapters on the landscapes of different

countries; and here we will just cite one or two special examples illustrative of the manner in which climate may modify the methods of cultivating the soil, and so forth. First of all we may note that a hard continental winter—as in Canada—brings all ploughing and sowing operations to a standstill; whilst a moist, open winter, as in Britain, affords many days when they may be carried on. Hence "winter-sown wheat" is a common expression in England.

Again, in drought-stricken Australia, everything turns upon a sufficient rainfall, not on sufficient sunshine, as in England. So fearful are the droughts in some years, intensified by the fierce heat of that sunburnt continent, that sheep perish of thirst by thousands, and the railway traveller may look out of the window to see the country-side dotted with carcasses, a terrible loss to the settlers.

To obtain sufficient pasture or fodder for sheep and cattle is thus a much more difficult matter than in England. Another result of the dry climate is said to be that wheat in Australia is "topped" instead of reaped, the straw being ploughed in again, as it is poor in quality and also not much required on the farm. The grain, however, is hard and dry, and of fine quality. The prevalent type of Australian scenery cannot be called beautiful, for the surface during the long summer drought presents a baked, brown expanse covered by thin, burnt grass; whilst the characteristic tree—the evergreen gum-tree—is ugly in form, and, turning its narrow evergreen leaves obliquely to the sun to catch as little light and heat as possible, affords but little shade. Of the necessity for irrigation in rainless countries, or those with a rainless season, we have already spoken.

Among the mountains climatic conditions are highly complicated, and, as a rule, severe; so that life is hard for the mountaineer, who, largely cut off from access to the outer world, must live on the produce of his own soil, however poor or unproductive that may be.

Think of the complex, local peculiarities of climate with which the Alpine peasants have to contend. One deep valley, tilted towards the south, gets too much sun, and becomes unbearably hot and close; another, opening towards the north, is entirely cut off from the direct rays of the sun, with the consequence that a hideous disease called cretinism—a form of idiocy—lurks among its inhabitants; yet another confined valley is so cut off from direct heat as to depend on the descent of hot föhn winds for a few days to ripen the grapes in autumn; while a fourth suffers local chill under the influence of a glacier stream creeping stealthily through the sombre pine-forest. One of the curious effects of such conditions is the laborious method of terrace cultivation which is in vogue in some of the high valleys of great mountain systems, such as the Alps in Europe and Himalayas in Asia. Soil is collected in the valley bottoms or wherever it is available in these rocky regions, and carried up such slopes as have a southern aspect, or such as manage to get enough sunshine, where it is laid out and partitioned into fields by means of stone walls, one above the other. In some places the mountain torrents are tapped by engineering work, so as to irrigate these agricultural terraces perched on the rocky sides of high Alpine valleys. In this terrace cultivation the climatic advantages of southern aspect are thus seized upon. Terrace cultivation may, however, be practised for other reasons, as in the fruitful island of Ceylon.

Since the relative feebleness of solar radiation in high latitudes is due to its oblique angle of incidence (Chapter I.), which itself depends upon the fact that the earth presents a curved instead of a flat surface to the sun, it is clear that where in such latitudes the land is tilted so as to catch the radiation vertically, there is locally produced one condition of the tropics. One may get a pretty good foretaste of tropical conditions during a walk on the steep southern face of the North or South Downs escarpment in the south of England, under a fierce July sun in a period of heat and drought.

Commerce is largely governed by climate in relation to the nature of the commodities which a nation finds it necessary to export or import, in the facility of transport, or even in the method of transport. Climate, for instance, at once passively permitted and actively compelled Britain to become a great commercial nation. For while, on the one hand, she is favoured with a climate sufficiently mild not to block her ports with winter ice, thus handicapping the maritime trade so vital to an island nation, on the other hand, Nature having given winter tempests in place of ice, she has to fight against the terrible seas which rage round her rocky shores; and it is by the conquest of the sea alone, by both her mercantile and naval marine, that Britain has attained the enviable position which she occupies among the Powers of the world, and been enabled to play so brilliant a part in history. The more so is this the case, because the economic development of the country, which has been governed primarily by the growth of industries to which a rich native coal-supply is essential, has necessitated the importation of the greater portion of the food-supply required for a vast

population, far exceeding what a cold wet climate and a small land area could possibly furnish, were every acre of available soil put to the plough. The construction of railways, roads, bridges, and buildings is normally controlled by prevalent conditions of temperature, wind, moisture, and other climatic elements in a variety of ways, an adequate consideration of which would involve a study of the practical application of meteorology to engineering, as well as special contrivances like the lifeboat, the fog-signal, and lightning-conductor. Special climatic effects in engineering may be observed in the extensive irrigation works of dry countries, in the works of defence against flood in wet countries, the close regulation by lock and weir of rivers particularly liable to cause floods after heavy rains, like the Loire in France.

Snow, again, in large quantities is a very serious obstruction to railway traffic, and hence the snow-plough is a machine kept in reserve in all countries liable to snow.

In Canada the work of the snow-plough may be said almost to form part of the ordinary service on the railroads, so constantly is it in operation during the winter months. In Scotland the Highland Railway very frequently gets blocked, and sometimes even the snow-plough itself is impeded; whilst, farther south, nearly every winter there are one or two occasions, between November and April, on which the express service between London and Edinburgh gets disorganised through snow on one or other of the three great routes. So enormous are the quantities of snow which fall in the Rocky Mountains that snow-sheds have been erected over the Canadian Pacific at dangerous points liable to avalanche falls.

Before the Trans-Siberian Railway was carried round the western end of Lake Baikal, the route of travel lay across the lake itself, and since the lake is frozen over in winter to the depth of three feet in places, the Russian Government ordered a Newcastle firm to construct a powerful ice-breaking train-ferry. The *Baikal*, as the vessel was called, was brought in parts from England to the shore of Lake Baikal, and there rebuilt, but the work of construction had often to be suspended during the terrible cold of the Siberian winter, as not only did the piercing winds cause great suffering to the workmen, but it was found that, whenever the temperature fell below 16° F. below zero (−16° F.), the ironware became too brittle to withstand the heavy blows of rivetting and caulking. The *Baikal* was propelled by three triple-expansion engines, and, it is said, could force her way easily through the ice, splitting it with her sloping bows and thrusting it sideways under and over the main floes.

Railroads which are carried across deserts have to be guarded against the blasting effects of wind-driven sand, whilst in the moister parts of the tropics railroad construction is often greatly handicapped by the destructive agency of the overpoweringly luxuriant vegetation.

Among textile industries, the great cotton industry of Lancashire has been eminently favoured by the damp climate. This industry is first under geologic control, since it was brought into being by the abundance of coal on the Pennine slopes of East Lancashire; secondly, it is controlled climatically by the enormous rainfall over the Cumberland hills and Pennine moors, which is conducted from Lake Thirlmere and artificial reservoirs, and so utilised to supply Manchester and the cotton districts of East Lancashire with an abundant

supply of pure water, so essential to the growth of a vast population; and, thirdly, the operation of cotton-spinning itself is favoured climatically by the very moist atmosphere of that part of England. The cotton industry requires, therefore, coal to furnish the steam-power, water to supply the population applying it, and humid air to permit the successful spinning of the fibre, all of which are present in or near Lancashire. But while the Lancashire climate has favoured the cotton and other industries upon which her teeming population depends, the industries themselves have attained such dimensions as to react very seriously upon the climate; for the appallingly gloomy and indescribably leaden skies, superimposed upon the normal dulness of a damp climate peculiar to this great industrial district, are such as to indicate the price which must be paid when human industry reaches such undue proportions that the air is poisoned and the earth befouled by myriads of factory chimneys ceaselessly belching out smoke of the blackest dye. Many Lancashire children are thus deprived in tender years of that play in the green fields which in so green a land as England might almost have been considered their birthright.

CHAPTER VII

THE INFLUENCE OF CLIMATE UPON MAN

PART III. RACE AND NATIONALITY.

I. Physical Characteristics.—The whole subject of the racial divisions of man and their origin is wrapped to a great extent in obscurity, and we do not propose to dwell upon the diverse conflicting theories current among ethnologists, but only to observe how the subject may be intelligently viewed in relation to climate.

To begin with the four great colour divisions of mankind, which are perhaps the most striking—white, yellow, red, and black—can these be wholly or partly attributed to varying climatic conditions upon the earth's surface? We must remember, in the first place, that climate is one of the most important factors in man's physical environment, by which he is necessarily affected. Seeing that the black race is native to Africa and Australia, the yellow race to Asia, the white race to Europe, we might be tempted to assert, without further reflection, that the black skin is the result of a hot climate, the yellow of an extreme continental climate, and the white of more equable oceanic conditions; and there are, as we shall see, reasons for supposing climate to have had an important share in the development of these differences.

Climate, however, cannot be the only factor concerned in the production of these major colour distinctions (associated with differences in the shape and structure of the hair, in the shape of the skull, delineation of features, and so forth), for we are immediately confronted with the question, Why is the red race (considered by some as only a modification of the yellow race of Asia) indigenous to the whole length of the American continent, from the frozen north, through the heat of the tropics, to the raw, chilly region of Tierra del Fuego in the extreme south? Geologists now suppose, from changes which have taken place in the distribution of land and water, and from the discovery of rude flint implements of very similar pattern in far corners of the world, that primitive or pleistocene man, as he is called, had some 100,000 years ago spread all over the land-surface of the globe, and that the great races of man were developed or specialised in different areas. The black race, in this view, seems actually to have sprung up on African soil, the yellow on Asiatic, the red on American; but, curiously enough, the white men, before migrating to Europe, now their natural home, appear to have originated in the Sahara region of Northern Africa, which probably had a cool, moist climate at a period when Northern and Central Europe lay under a sheet of ice, as Greenland does to-day. However this may be, let us see what evidence there is for holding climate responsible for the colour divisions of man.

It was Charles Darwin who first satisfactorily expounded the laws whereby living organisms, animal or plant, undergo variations arising either in response to external conditions or spontaneously—that is, as a result of the inherent tendency for living beings to

depart from the original parental standard, giving rise to individuality; and he showed that in the fierce struggle for existence to which animals and plants are subjected in the wild state, those individuals showing variations, however slight, which happen to be useful or advantageous to them—varying, so to speak, in the right direction—have an advantage over their competitors, so that in the course of time, the serviceable variations being continually perpetuated, new varieties and species of animals and plants are developed by a process of natural selection.

Now, on the assumption that primitive man had spread all over the globe (no matter where he originally came from) before the great races of men were developed in the regions mentioned above, what we have to ask ourselves is, What are the factors which could have co-operated to produce such striking differences in appearance as we see in the black Negro, the yellow Mongol, the red American Indian, and the white European?

The chief external factors are climate, diet (depending on both climatic and geological conditions), and work (depending on climatic, geological, topographical, social, and political conditions); so we see that climate, directly or indirectly, is the most prominent factor in the immediate physical environment of man, and should take the lion's share in modifying his physical characteristics.

First of all, let us take the blacks. The primeval home of the negroes was in Africa and Australia; they persist in those regions to this day, and have extended in modern times to the hot parts of America; and the inhabitants of all warm countries tend to become dark-skinned like the Hindoos, who have, but for their dark

colour, nothing whatever in common with the Negro race, and are classed with the white European (Caucasian) stock. From these facts there is every reason for concluding that the heat, as probably also the moisture, of the tropics has blackened the skins of the African natives. Against this conclusion it has been argued that, since black bodies absorb more heat than white ones, and so become hotter when exposed to the sun's rays, a black skin is the worst the negro could have, and that natural selection should in the course of ages have produced in him a white skin. But theory breaks down before fact, and if natural selection has not developed a white race in Africa, it only shows this —that the black colour could not have arisen spontaneously (for, being disadvantageous, any original tendency to darkness of skin would have been stamped out), and that it is the effect of environment, of which climate, as we have seen, is the most important element, which has produced the black skin and permitted it to be inherited through the ages.

At the same time, it must be noted that the dark skin of the face may serve to protect the eyes from the fierce sunlight in the tropics, so that any spontaneous variations towards black skin may to a certain extent have been naturally favoured, although the primary cause of the darkened skin was the physical effect of the sun's heat. Unfortunately, the human eye is not strong enough to endure without discomfort or injury the excess of reflected light liable to occur normally on the surface of the globe, and so we find that in those regions where the nature of the surface is of such a character as to reflect with intense glare the rays of the sun, as amid the sands of the Sahara and the snows of the Himalayas, the natives blacken the eyes to protect

them. Even in England, persons at the seaside in the summer months sometimes find the use of eyeglasses just slightly darkened with carbon advantageous to avoid the shimmer observed in the strong reflected light from sea and sky.

The yellow skin of the Mongolian race, which originated and persists in all parts of Asia except the tropical countries, may perhaps be due to the excessively dry continental climate, with a far vaster range of temperature between summer and winter than occurs in Europe. But as the most northern people in the world, the Eskimos, who live along the shores of the Arctic Ocean in Europe, Asia, and America, also belong to the yellow race, it would seem that the primary factor in the development of the yellow colour is severe cold during some portions of the year, together with all that severe cold involves in the way of diet, etc. All parts of Asia north of the line of the Himalayas are intensely cold in winter, and it is noteworthy, in support of the contention that the yellow colour arose from extreme temperature conditions and a dry atmosphere, that the Russians, experiencing a climate more nearly Asiatic than any other European nation, lack the fair complexion of West European people.

Coming now to the white race, we find this to include not only the actual white Europeans, but also the brown or black skinned Hindoos, Arabs, Berbers, and Hamites in South-Western Asia and Northern Africa, all of whom are comprised by ethnologists in the great "Caucasian" race, and afford additional evidence that dark colour is due to heat. Many of the inhabitants of North Africa, however, are relatively fair, even in comparison with those of Southern Europe, and it may be that the excessive dryness of this part of Africa

has tended to act oppositely on the skin to the intense heat.

Among the white Europeans themselves we find broad general physical differences between the Northerners and the Southerners, the former having fair skin, hair, and eyes, and tall stature ; the latter, swarthy skin, black hair, dark eyes, and small stature—the last characteristic not implying a feeble physique, since the Spaniards are remarkable for great muscular strength. The beautiful clear, fresh complexion prevalent among English people, and so much admired abroad, is due, like the verdure of the English fields, to the cool, moist, equable climate; and as one travels eastwards into continental Europe, the skin becomes coarser and more wrinkled as a result of greater dryness and fiercer extremes of temperature.

The Red Indians of America are more difficult to relate to specific climatic conditions, and we can only suppose that something in their physical environment has gradually developed the peculiar coppery or reddish-brown skin and black hair by which they are characterised, and that in whatever part of America the race was originally specialised, it found, on dispersing over the whole continent, conditions not unfavourable to the preservation of these physical traits. It has been pointed out that the curly hair of the Englishman becomes lank among his descendants in the United States of America, resembling that of the native Indians; and that this seems to be connected with the change from a very damp to a very dry climate, as may likewise be associated the greater brittleness of the finger-nails and more rapid decay of teeth amongst the people of the United States. Similarly, English settlers in Australia are said to develop a roughness of the hair and beard almost

like that of the Australian aborigines; so that climatic influence in all these cases can scarcely be doubted.

Dwarfed stature has resulted from severe cold and the long Polar night among the Eskimos, and from deprivation of sunlight among the pigmy tribes of the dark Congo forests in Equatorial Africa. Both tribes are so deprived of adaptability by unwholesome climatic conditions, and possess such little power of adjusting themselves to new surroundings, that when the Eskimo is brought to England, he succumbs to pneumonia, and when the Congo negrito emerges from the forest into the sunlit plains of the Sudan, he is liable to fall ill and wither away, although cases are on record of improved physique following the change of environment.

II. Mental and Social Characteristics.—In the last section we selected for study the colour divisions of mankind, because colour variations, perhaps, afford the most striking and sure criteria of the visible physical effects of diverse atmospheric conditions upon the human body. It should be remembered, however, that, as a general rule, any particular physical or mental characteristic which may be shown by the large primary groups of mankind, cannot be related to climate directly, but only indirectly, as a side-issue, so to speak, of the broader and more general characteristics to which climate may have given rise. One could not say that climatic influence was responsible for any particular depraved moral quality we might find in the African negro, or for any virtuous characteristic in a European, except in so far as the European climate has gradually developed man intellectually, morally, and physically to the highest grade he has ever attained, whereas the unhealthy climate of Equatorial Africa has kept him in a very low stage of civilisation.

But when we come to study the minor or special differences to be observed among peoples of the same great race—to study national rather than major racial differences—we find that these can often be attributed to climate more or less directly. To illustrate this we will contrast the northern and southern peoples of the white European race, and see how far climatic environment will account for national characteristics. Before doing so, however, we must touch upon the broader question of civilisation, the grade of which is necessarily the index of the mental and social development of the intelligent rational beings which constitute the human species.

With the exception of the American-Indian Aztecs and Incas, who, dwelling respectively on the healthy mountain plateaux of the tropical lands of Mexico and Peru, developed a fairly high civilisation before they were ruthlessly overthrown by the Spaniards, all civilisations of any importance in ancient and modern times have been, if we except an ancient civilisation in India and Ceylon, evolved in the Temperate Zone—in the North Temperate Zone only, owing to the accident of there being very little land in the South Temperate Zone.

It is curious, moreover, that whereas in ancient and medieval times the most civilised regions were the countries situated in the warm-temperate portion of the North Temperate Zone — viz., Greece, Italy, Asia Minor, Egypt, Arabia, and other lands—in modern times the rise to greatness of Britain, Germany, and France, together with the settled prosperous condition (though unattended by national greatness) of Holland, Belgium, and Scandinavia, subsequent to the decay of Greece and degeneration of Spain, has drawn the focus

highly intellectual and imaginative, and have produced men of the highest creative genius in the realms of science, philosophy, art, and letters. The four great modern nations, together with ancient Greece—Britain, Germany, France, and Italy—have each of them produced such a number of great men, so far excelling that of other nations that the lustre of the world's genius might be said to emanate from them.

Each of these four nations, be it noted, has moderate climates not very far removed on either side of the 45th parallel N. But whilst the climates of Northern and Southern Europe have both been favourable to the highest productions of the imagination, there yet remains the fact that the work of the imagination, as exemplified in English poetry and painting, trends in a different direction and adopts different modes of expression from that exemplified, for instance, in Italian; and it is, moreover, in the highest degree probable that the notable differences between the climates of Britain and Italy, which we have discussed in previous pages, has been a factor in effecting this contrast in the literary and artistic work of the two nations.

Considering the question of advanced civilisation in relation to climate, we must note especially the unique position of France. Lying in the middle of the Temperate Zone and cut by the 45th parallel, the seasons in France are better balanced than in Britain on the north, or Italy on the south; and, besides the favourable circumstance of the heat of summer being more or less equal in duration to the cold of winter, France possesses the particular advantages of being close to the Atlantic Ocean, which insures her an abundant rainfall from the westerly winds, and of having a vast extent of level surface forming a rich and productive

soil. It is not surprising, therefore, to find France a rich, self-supporting agricultural land; and as a result of this enviable economic condition, due to climate and soil, there do not exist in France the terrible depths of poverty set amid great wealth that are so sad to see in our own country. On the other hand, there are, as we have suggested in Chapter III., subtle influences in the climate and soil of their island home that have caused the English nation as a whole to love the open country and to cultivate manly outdoor sports and pastimes: and it is partly in this; partly (as our late Queen Victoria is reported to have said) in the fact that children of the richer class are brought up in proper homes and not in "flats," as abroad; and partly, no doubt, in the public school system, which directs boys to rule themselves rather than be over-ruled by their masters—that we have the underlying secret of England's strength and national greatness.

The Hindoos, who, despite their brown skin, belong to the same great race as the Europeans, show climatic influences very clearly in their mental characters. The Hindoo mind is extraordinarily subtle, though less deep than the European. India is the land of magic art and occult science. Hindoo artistic work is feverishly grotesque and fanciful, and in the frequent distortion of the limbs of men and animals shows a degraded imagination. No doubt the fierce vertical sun is at the back of these unhealthy tendencies in Hindoo pictures, for just as the tropical climate is incompatible with full bodily and mental vigour, so it may also be incompatible with the highest and purest expression of the human imagination in art, letters, and religion. Some of the superstitions of India, as, for instance, the *Churee* of which Kipling speaks, are positively fearful,

affording fine illustrations of those malignant creations of the mind which will inevitably originate among a teeming mass of people dwelling in the exciting and unwholesome conditions of a burning tropical land.

III. Racial Migration: Colonisation.—The history of the migration of races and the successful colonisation of new lands teems with interest from the point of view of climatic control. It may be laid down as a general rule that, while much will depend upon the capacity of any particular race of people to adapt themselves to new surroundings, colonisation is easiest and most successful where climatic conditions approach most nearly those of the mother-country.

The strong and vigorous British people have shown a wonderful power to acclimatise themselves in new surroundings, as is evident from the diverse climatic conditions which occur in various parts of their enormous Empire. Canada resembles Britain climatically in being more or less in the same latitude; but from the point of view of moistness and equability the extremely salubrious climates of New Zealand and Tasmania, though rather warmer and still more equable, most nearly approach that of the mother-country. South Africa and Australia (except Queensland in the northern tropical part), hot as they are, have a decided, if short, winter season, and the climate is not prejudicial to the health of English settlers; but in India we have, climatically, the weak spot in the Empire. We have seen that tropical climates are injurious even to the natives, let alone settlers from temperate regions, who may have political possession of, but never colonise, a tropical land, as is the case in India; and it is no doubt true that British rule in India has been rendered more difficult than it otherwise would have been, from the

incapacity of our children to be reared in that country. At all events, the facts indubitably argue a weak spot in the physical substratum of the Empire of which we British who value India, and still more the integrity of our glorious Empire, must ever take heed, by doing all in our power to counteract the evil effects of climate.

We thus see that in a very real sense climate may be said to control our mighty Empire.

The history of the development of European nations exhibits some highly instructive examples of the control of climate over the migratory movements of the different local races, operating behind, as it were, the more immediate directing factor of political causes. Thus, the Teutonic tribes of Germany, crossing the North Sea into Britain, finding there climatic conditions broadly similar to their own, remained there, and eventually developed themselves into the main constituent of the present English nation; but of the various German tribes which at different periods moved southwards into Spain and Italy, all had sooner or later to retreat northwards in face of the Mediterranean races better adapted to the climates of those countries.

Conversely, the Romans, in expanding to the north of Europe, were never so much at home as in those countries of their empire situated more in their own latitude; and, though they held Britain for 400 years, they finally left the country without having amalgamated themselves in any way with the native Britons, and without having left a permanent impress upon the character and language of the people to anything like the same extent as they did in France, Spain, Portugal, Italy itself, and Greece.

Religion.—In common with the other mental developments of the human race, the diverse systems of religious belief which prevail over the globe are subject in some measure to the effects of general geographic, including climatic, environment.

Speaking broadly, the effect of climate upon religion is only indirect, working through the general level of culture of the particular race, as illustrated by, *e.g.*, the crude forms of fetish or spirit-worship current among savages intellectually so undeveloped as to be unable to form the abstract conception of God on the one hand, and the high moral precepts of Christianity among the European people on the other. But when we consider special regions of the world, we find reason to suppose that climate, if it has not been a main instrument in giving rise to the particular system of religious belief held therein, has at least been a factor in colouring forms of worship and creed in one direction or another.

It has been demonstrated, for example, that the map of the rainless desert tracts of Africa and Asia practically coincides with the "Mohammedan" map of the world, and no doubt there is, as has been argued, something in the desert environment conducive to the development and persistence of Mohammedanism.

When, further, we consider the Christian countries of Europe, we may be quite sure that climate operating behind, as it were, the more immediate racial, political, and moral factors concerned, has been favourable to the localisation of Protestantism in the north of Europe, and of Roman Catholicism mainly in the south.

Of course, racial, political, and moral factors have been the immediate cause of the localisation of the Protestant forms of Christian worship in Northern Europe, and of the Roman Catholic form in Southern.

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Of course, racial, political, and moral factors have been the immediate cause of the localisation of the Protestant forms of Christian worship in Northern Europe, and of the Roman Catholic form in Southern.

But in all methods of scientific analysis we have to deal, not with a single cause, but with a chain of causes; and if the moral forces which led to the establishment of the Reformation in the north of Europe, were the first or nearest link in the chain of causes, climatic influence—that ever-present background, from whose subtle, but sure, effects men cannot escape—was assuredly the farthest or last.

If the case for climate, however, as a factor in the distribution of religious creed in Europe rested mainly on geographical position, it would be no more than a probability; but it becomes certain when we consider how much better adapted on the whole Protestantism is to the northern temperament and Romanism to the southern. The northern nations sooner or later revolted from the sway of Roman Catholicism, because the latter proved irksome to them and is uncongenial to their sentiments; while the individualism of Protestantism, so sacred to Englishmen, is quite incomprehensible or uncongenial to the Latin temperament.

It is truly and grandly said that the moral strength of the English nation has been founded upon the Bible, and it is Protestantism, we must remember which is congenial to the national temperament, tha permits direct access to, and free judgment upon, th teaching of the Bible, with its infinite beauty of thoug and diction.

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In view of the various factors involved in the growth of religious systems, we should not, of course, expect to find the localisation of Protestantism and Romanism in the north and south of Europe respectively absolute. Thus, in the north of Europe we find exceptions in the Irish, who are largely Roman Catholic,—in the Belgians, almost entirely Roman Catholic,—and in the

Russians, who are subservient to the Greek Orthodox Church, which is so similar to the Roman Catholic Church in creed and general observances that for our present argument it may be considered one with it; while in Switzerland we find an example of Protestantism occurring farther south in Europe than usual.

CHAPTER VIII

METEOROLOGY

In the first chapter of this book we discussed the meaning of climate in order to stimulate our interest in the study of the control it exercises over the surface of the earth and the life upon it, and now, in the concluding chapter, we will study a few of the chief meteorological elements, which, as we have seen, go to make up climate. It is impossible to outline the rudiments of meteorological science within the limits of a single chapter, and the subject can only here be introduced in its special bearing upon the preceding chapters on climatic control.

I. Definition of Meteorology.—Meteorology is the name given to the science which treats of the changing phenomena of the gaseous envelope, or atmosphere, surrounding the solid and liquid surface of the earth. In other words, it is the science of the weather—the name we give to the sum total effect of pressure, temperature, wind, cloud, sunshine, precipitation, and electricity as observed at a particular time and place. The word "meteorology" is derived from the Greek *meteoros* and *logos* (a discourse of the things above the earth). The ancient Greeks, deeply intellectual as they were, lived in a relatively undeveloped age of the world's history, and their greatest men held views upon scientific matters which seem very crude to us. Thus, they classed both astronomical and meteorological phenomena to-

gether as *ta meteora*. Nowadays, however, the sciences of astronomy and meteorology are as distinct as two branches of natural knowledge can be. Curiously enough, the celestial objects to which we now give the name of *meteors* are not a meteorological or weather phenomenon at all, but an astronomical one, being the result of small solid bodies from outer space suddenly rushing into the upper levels of the earth's atmosphere, where they are converted by the heat due to friction, into luminous masses of harmless metallic vapour which condenses and falls as dust.

II. Composition of the Atmosphere.—The chemical composition of the earth's atmosphere will be found discussed in many textbooks either upon inorganic chemistry or upon meteorology. Suffice it here to say that the vapour of water which the atmosphere contains, though present only in very small quantity in comparison with the two chief gases, oxygen and nitrogen, is, from a purely meteorological point of view, the most important constituent, since all changes of weather are connected with its varying quantity and varying condition with regard to condensation.

III. Meaning of Weather.—It was shown in the first chapter that climate is made up of a number of average meteorological elements as well as a number of astronomical elements. The astronomical elements—viz., the altitude of the sun and the length of the day, two rigorously interdependent functions—are fixed for a given season and latitude; and, though they powerfully influence the atmospheric phenomena which we denote by the term "weather," they do not enter into the composition of the weather as ordinarily understood, which is made up of meteorological elements only. The chief elements of weather are: Pressure, tempera-

ture, relative humidity, wind, sunshine, clouds, and precipitation, effects due to refraction and reflection of light, and electrical manifestations.

The weather may be defined as the sum total effect in the atmosphere, at a given time and place, of pressure, heat, moisture, wind, light, dust, and electricity.

IV. The Pressure of the Atmosphere.—The air in which we live and breathe, in virtue of the attraction of the earth upon its mass—in virtue, that is to say, of its weight—exerts a pressure upon all bodies situated beneath it or in it. This pressure amounts on the average upon the earth's surface at the bottom of the ocean of air to 14·7 pounds upon the square inch (1033·3 grammes per square centimetre); but since the air is a compressible fluid—that is, a gas—it undergoes considerable variations in density under the influence of heat and mechanical forces, and so the elastic force or pressure which the air exerts in all directions varies within certain limits, more or less well known, and capable of being accurately measured.

As a result of its compressibility, moreover, the ocean of air has no "top," no definable upper limit, as the nearly incompressible ocean of water has; but the bottom layers are the densest, being subject to the pressure of the layers above them, which get continually less and less dense as the height is increased, till at some 200 miles above the land or water surface of the earth the atmosphere is so thin, or rare, that it would be impossible to say where the air ended and empty space began. The decrease of pressure for a given increase of elevation is, as a necessary consequence, much more rapid at low levels than in the upper regions of the atmosphere, so that at a height of 18,000 feet, or about three miles, above the sea one-half of the atmosphere by mass lies below; in other

words, at an altitude not very much greater than the summit of Mont Blanc (16,000 feet) the pressure is reduced to one-half what it is at sea-level. During the first 900 feet in ascending above sea-level the mean pressure falls as much as 1 inch, and at the top of a lofty house the barometer reads some tenths of an inch lower than at the bottom.

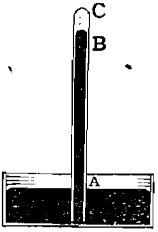


FIG. 1.

A B = difference of level of mercury in tube and cistern = Barometric height.

B C = Torricellian vacuum.

Of the various types of instruments which have been invented for recording the pressure of the atmosphere, the most generally employed is the mercurial barometer, the principle of which was discovered by the Italian physicist Torricelli. If you take a glass tube, about 34 inches long, closed at one end, fill it with mercury, place your thumb over the open end, and invert it in a dish or tray filled with mercury, you will find that the mercury remains in the tube, forming a column about 30 inches high, which is supported by the column of air over the mercury in the dish, extending to the upper limit of the atmosphere (Fig. 1). The pressure of the air then balances a column of mercury about 30 inches (or 760 millimetres) high, leaving an empty space, known as the "Torricellian vacuum," between the top of the mercurial column and the top of the tube containing it. The specific gravity of mercury being 13·6, and that of glycerine 1·3, as compared with water, the very simplest statement in arithmetical proportion will show that the barometric column in a water barometer would be nearly 34 feet in length, and that in a glycerine barometer 27 feet, instead of only 30 inches.

At sea-level, the normal variations of atmospheric

pressure in association with weather changes are between 29 and 31 inches, but these average limits are occasionally considerably exceeded.

The human body is, unfortunately, not well adapted to live in air whose density is much in excess or defect of the sea-level value. Thus, in deep mines the increased pressure acts deleteriously upon the health of the workmen, whilst the lessened pressure at high levels renders mountaineers liable to "mountain sickness," doubtless acting as a deterrent upon many would-be climbers.

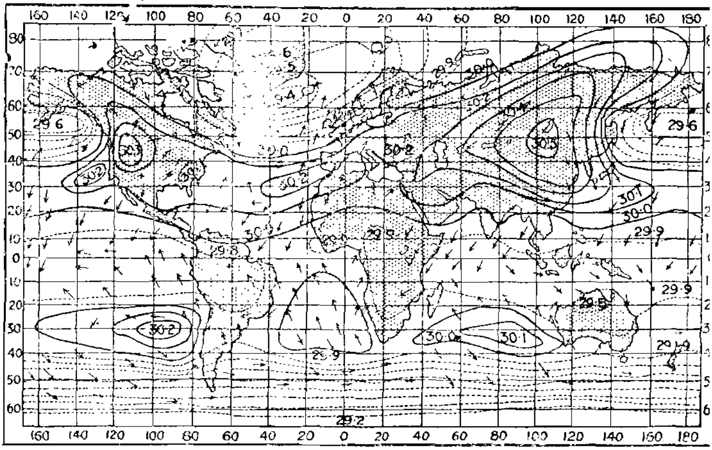
V. Variation and Distribution of Atmospheric Pressure.—The elastic pressure exerted by a given mass of a true gas like atmospheric air depends upon two conditions: (1) Its *density* (which density varies inversely as its volume if the temperature remains constant—Boyle's Law); (2) its *temperature* (with which temperature its volume varies directly if the external pressure upon it remains constant—Charles's Law). See Appendix.

One must refer to treatises of physics for a fuller explanation of these important laws.

In the experimental verification of these laws of gaseous bodies we have to confine our mass of air in some suitable vessel in a physical laboratory, and vary its volume at will by the application of heat or mechanical force. In meteorology, however, unlike experimental physics, the *given mass* of air whose laws we have to investigate, is the entire atmosphere enveloping the earth considered as a single unit. The mass of air per unit volume is constantly varying over any particular locality—in other words, the air density as indicated by the rise and fall of the barometer changes—and it is for the meteorologist to study the

causes of these pressure variations, together with the resulting horizontal distribution of atmospheric pressure over the land and water surfaces of the globe.

The original cause of local differences in atmospheric pressure is the unequal heating of the earth's land and water, but especially the land surface, by the sun's rays. During the day-time at all seasons in low

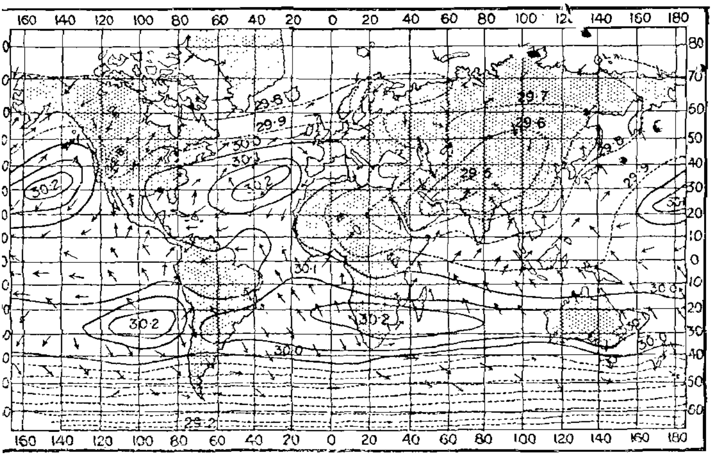


MEAN DISTRIBUTION OF ATMOSPHERIC PRESSURE AND PREVAILING WINDS FOR JANUARY, THE MONTH WHEN THE WINTER DISTRIBUTION IS MOST PRONOUNCED.

(Barometric pressure in inches of mercury.)

latitudes, and during the summer in high latitudes, the solar radiation, in warming the surface and the superincumbent air causes the latter to expand and rise with a necessary reduction of atmospheric pressure over a place beneath this (see Chapters I. and II.) volume of air. Conversely, at night-time at all seasons in low latitudes, and during the winter in high latitudes,

terrestrial radiation, in chilling the air over the ground, causes it to contract vertically and laterally, with a necessary increase in atmospheric pressure. The result is that air tends on the whole to flow from regions of high pressure, where it is cold, to those of low pressure, where it is warm; and this is the first stage in the development of that circulation of the atmosphere



MEAN DISTRIBUTION OF ATMOSPHERIC PRESSURE AND PREVAILING WINDS FOR JULY, THE MONTH WHEN THE SUMMER DISTRIBUTION IS MOST PRONOUNCED.

(Barometric pressure in inches of mercury.)

without which living beings as actually constituted could not dwell on the surface of the earth. If the circulation of the atmosphere depended merely upon local inequalities of pressure consequent upon inequalities of temperature, it would be comparatively simple, as equilibrium would be rapidly restored between hot and cold areas. This, however, is not the case, for as soon as air begins to flow from a region of higher to

one of lower pressure the effect of the rotation of the earth upon its axis comes into play in modifying its subsequent motion. The fact is, and the cause may be demonstrated mathematically, then, that when air begins to flow in any direction from higher to lower pressure it is deflected by the force, due to the rotational velocity of the earth (not the revolutional

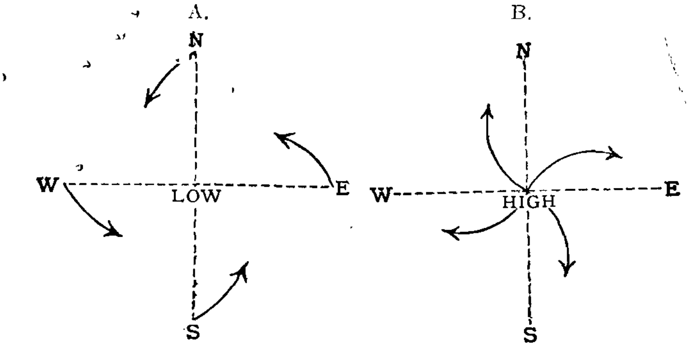


FIG. 2.

CYCLONIC ACTION: NORTHERN HEMISPHERE.

Here we may suppose currents of air, originally tending to flow *towards* the centre of *low*-pressure as N., S., E., and W. winds in the direction of the dotted lines are deflected to the right by the earth's rotations into N.E., S.W., S.E., and N.W. winds respectively, as indicated by the arrows.

The result is that the winds in a cyclone circulate round its centre of low pressure in a direction opposite to that of the hands of a watch in the Northern Hemisphere.

In the Southern Hemisphere the N., S., E., and W. currents would be deflected to the N.W., S.E., N.E., and S.W. winds respectively, and hence cyclonic circulation south of the Equator is with watch hands.

ANTI-CYCLONIC ACTION: NORTHERN HEMISPHERE.

In this case the air flowing outwards *from* a centre of *high* pressure is deflected in the same way to the right of the earth's rotation, with the result that anti-cyclone circulation takes place in a clockwise direction in the Northern Hemisphere.

South of the Equator, the air being deflected to the left, anti-cyclonic movement becomes anti-clockwise.

velocity), to the right of the initial direction in the Northern Hemisphere, and to the left in the Southern.

The effect is, by heaping up air to the right or left, greatly to increase the initial difference of pressure which originated the movement of air, and to develop the great wind currents which circulate in endless complexity over the globe.

The deflection of air-currents by the earth's rotation is illustrated simply in Fig. 2, A and B. In A we have the essential principle of cyclonic circulation, and in B of anti-cyclonic circulation.

The cyclone and the anti-cyclone are the two primary types of atmospheric movement, and all great weather systems are associated with their action or modifications of it. In cyclonic circulation the pressure decreases very rapidly from the outskirts of the system to the centre of low pressure. In other words, the "pressure gradients" are steep, a fact which results in strong winds or violent gales; but in anti-cyclonic circulation the pressure gradients are usually slight, and the air moves sluggishly outwards. The reason is that in a cyclone the air as it draws near the centre revolves faster and faster in accordance with a principle investigated by Sir Isaac Newton, that when a stone is whirled round at the end of a piece of string, which is at the same time drawn in by being wound round a stick, the stone revolves faster as the string gets shorter; but as the air revolves faster centripetal or "centrifugal" force increases, with the result that the air tends somewhat to keep away from the centre, the pressure gradient thus becoming steepened. In an anti-cyclone, in which the mass of air is moving outwards from a centre, and not inwards towards a centre, no such force usually comes into play.

The circulation of the atmosphere which takes place between the hot Equator and the cold poles is very

complicated, as a result, not only of the effect of the earth's rotation, but of other causes connected with the fact that once a fluid, like air or water, is set in motion, this very motion tends to engender internal movements in the shape of eddies in a manner that we do not fully understand.

Water as well as air, when set in motion, is liable to break up into eddies of high or low pressure, but since water is a nearly incompressible fluid (liquid), and not a compressible fluid (gas) like air, a water cyclone is a region, not of diminished density, but of diminished height—that is to say, the surface of an eddy is depressed below the general level of the water, sometimes to such an extent as to form a funnel-shaped cavity. Conversely, a water anti-cyclone cannot take the form of increased density, but manifests itself in increase of height—in the shape of a "backwater"—although in this case a true eddy movement may not be developed.

It was Ferrel who first gave a fairly satisfactory exposition of the general circulation of the atmosphere, showing that the Trade-winds, deflected by the earth's rotation from north to north-east in the Northern Hemisphere, and from South to South-East in the Southern, flow to supply the diminished pressure over the Equator, where the hot air rises into the upper atmosphere, there flowing outwards over the Trades in the opposite direction, and finally descending to the earth's surface as west-south-westerly winds in the North Temperate Zone, and west-north-westerly in the South Temperate Zone.

Many atlases contain a map showing the average general wind circulation at the *surface* of the earth, together with the chief ocean currents which the winds

mainly engender. The maps on pp. 139, 140 show, for the months of January and July, the distribution of atmospheric pressure, which establishes this set in the wind-currents.

It will be seen that pressure is highest over the continents in winter, and lowest in summer.

Recent polar observation has tended to show (Chapter II.) what theory demands—namely, that pressure is relatively high over the polar regions, the air flowing out anti-cyclonically towards the low-pressure regions of the colder portion of the Temperate Zones, in which the British Isles, for instance, lie.

VI. The Temperature of the Atmosphere.—The atmosphere is heated partly by the direct rays of the sun which pass through it, and partly (sometimes chiefly) by contact with the ground, which is first warmed by the sun, the superincumbent air then taking up the temperature of the soil through the establishment of "convection" currents (see works on physics).

When the air is very damp, even if the sky be clear, it absorbs a large proportion of the solar rays which pass through it, so that the radiation which penetrates to the ground is relatively feeble. Similarly at night-time the heat, which is radiated from the earth to the sky, is to a large extent absorbed and reflected, or radiated, back to the ground, with the result that damp or cloudy nights are at all seasons relatively warm (unless, of course, cold winds blow), with little deposition of dew in summer or rime (hoar-frost) in winter in comparison with dry, clear nights.

Dry air is thus said to be more transparent to heat (diathermanous) than damp air.

In order to understand the chief of the *three reasons*

(Chapter II.) why it is that the surface of the land is hotter in summer and colder in winter than that of the sea, it is necessary to master once and for all the conception of what is meant by specific heat. This is the relative amount of heat required to raise a given mass of a body from one temperature to another. Water has a very high specific heat, which is usually taken as the standard, and called unity. Most other substances, together with the rocks and minerals forming the land surface of the earth, have, in comparison with water, a low specific heat—that is, they require, mass for mass, a smaller quantity of heat to raise their temperatures a given number of degrees than water does. The result is that, for a given quantity of solar heat energy striking equal areas of land and sea, the land is heated up to a higher temperature than the sea; but when the source of heat is withdrawn, the land cools down at night, and in winter to a lower temperature than the sea, which thus acts as a conservator of heat. Heat, it must be remembered, is a form of energy, convertible into other forms, and measurable as a quantity. Temperature is merely the molecular condition of a body with respect to the amount of heat it contains. The molecules of a body at a higher temperature are vibrating more rapidly than those of one at a lower. Reflection will show, therefore, that water, having a high specific heat, requires to absorb a far larger quantity of heat to set its molecules vibrating—that is, to raise its temperature—than sand does, for instance. Owing to this great difference in specific heat, there is an enormously greater quantity of heat in a pound of ice-cold water beneath a frozen pond in winter than in a pound of sun-baked sand by the seashore in summer, so hot as to burn one's naked feet.

The upper atmosphere far above the earth's surface,

which is too rare to be appreciably warmed by the sun's rays passing through it, and quite out of reach of the convection currents near the surface, remains everywhere in all latitudes at a very low temperature—far below the freezing-point of water (Chapter I.). The temperature of the air is measured by meteorologists with Kew-certificated thermometers, placed in a suitable form of screen to protect them from the effects of direct radiation from the sun and ground. The highest authenticated air temperature ever recorded in London at the Royal Observatory, Greenwich, is +100° F. (+37·7° C.), and the lowest −10° F. (−23·3° C.), which are fairly severe extremes of heat and cold, considering the insular character of the climate of England, which, however, is less marked in the neighbourhood of London than in some other parts of the country more remote from the mainland of Europe.

The heating effect of the sun's rays upon the ground varies for a given clearness of sky and dryness and temperature of the atmosphere with the amount of wind present; and we all know that in summer-time objects out in the garden exposed to the sun get much hotter when it is calm than when a breeze is blowing, causing free interchange of air round them.

VII. The Humidity of the Atmosphere.—The amount of water-vapour, or "moisture," which the air can hold depends, as we learn in physics, on the temperature of the air. It would perhaps be more correct to say that it depends on the temperature of the vapour itself in passing upwards from a water surface; but since the mass of air into which relatively small quantities of vapour pass immediately gives its own temperature to the vapour, it amounts to the same thing to say that the amount of water-vapour which

can be contained in a given volume of air is determined by the temperature of the air. In reality there is for every temperature a certain maximum quantity of water-vapour which in presence of liquid water can be contained in a given volume whether air be there or not, and when this maximum quantity of vapour exists, it is said to be saturated, which means that the vapour is at the point of undergoing condensation into mist or cloud. It is obvious, therefore, that air containing a quantity of vapour in the unsaturated or dry condition, in which it behaves as a true gas—like the air itself—can be cooled down to a certain critical point, known technically as the "dew-point," at which the contained vapour becomes saturated, any further reduction of temperature resulting in the condensation of a certain proportion of the vapour, which then usually becomes visible as cloud, mist, or fog.

The actual amount of vapour present at any time is known as the "absolute humidity"; the ratio of this to the quantity which would saturate the air at the actual temperature is called the "relative humidity." It is upon the relative humidity that we base all our sensations of dampness and dryness, and estimate the hygrometric condition of the atmosphere. From a climatic point of view, the relative humidity of the atmosphere is nearly as important as the temperature. In many warm countries, which, like Egypt, are excessively *dry* (on account of low relative humidity), the absolute humidity is high, as it must always be in low latitudes, where evaporation takes place vigorously.

We have already learned why the hot Equatorial belt is damp. The British Isles have a very high average relative humidity (80 to 90 per cent.)—that is, a very damp atmosphere—because they are surrounded by a

relatively warm ocean, giving off vapour at a temperature too high for the cold latitude in which they are placed. When a long spell of really dry *atmosphere* (relative humidity below 50 per cent.), as distinct from dry *weather*, does occur in the British Islands, it is generally in the spring—March or April. Such a spell is always rather unhealthy, being favourable to sore throat and general febrile disturbance, the reason being partly because the dry air—usually a searching easterly wind—causes brisker evaporation from the skin than persons living in a damp climate are accustomed to bear, and partly because in such weather there is often a severe contrast between hot sunshine by day and keen frost at night.

The standard method which meteorologists have adopted of estimating the relative humidity of the atmosphere is a comparison of the readings of a pair of thermometers known as the "dry and wet bulb thermometers." The two thermometers are of similar pattern, and mounted a short distance apart, the bulb of one being wrapped in muslin, kept moist by means of a cotton wick dipping into a vessel of water. The evaporation from the muslin surface, which, of course, varies in rapidity with the dryness of the air—that is to say, with its avidity for moisture—lowers the temperature of the thermometer bulb below that of the dry thermometer, and a comparison of the two readings furnishes data for calculating the relative humidity of the air as a percentage. The difference between the dry and wet bulb readings is greater for the same degree of humidity at high than at low temperatures. Examples:

1. Dry bulb = 80° F.; wet bulb = 77° F.
2. Dry bulb = 40° F.; wet bulb = 37° F.

Now, to obtain the relative humidity from these data, we must first of all, in each case, calculate the dew-point, which is done by subtracting the wet-bulb reading from the dry-bulb, multiplying the difference by a factor, and subtracting the product from the dry-bulb reading. The factors required are to be found in a set of tables compiled by Glaisher, and on referring to them, we find that for a dry-bulb reading of 80° F., the proper factor is 1·68, and for a dry-bulb reading of 40° F. the factor is 2·29. We get, therefore—

$$80 - (80 - 77) \times 1{\cdot}68 \text{ and } 40 - (40 - 37) \times 2{\cdot}29$$
$$= 74{\cdot}96^\circ \text{ F. and } 33{\cdot}13^\circ \text{ F. respectively;}$$

or, approximately, 75° and 33·1°.

Now, the maximum vapour tensions, or saturation pressures of aqueous vapour, expressed in inches of mercury, at the temperatures 80·0°, 75·0°, 40·0°, and 33·1°, are respectively 1·023, 0·868, 0·247, and 0·188; and from these data, by a simple statement in proportion, the percentage humidity of the air is obtained. If the air were saturated at 80·0° and 40·0°, the tensions would be 1·023 inches and 0·247 inch respectively, but they are actually only 0·868 inch and 0·188 inch, so that we get for the percentage humidities:

1. 1·023 : 0·868 : : 100 : $x = 85{\cdot}8$, or say $= 86$ per cent.
2. 0·247 : 0·188 : : 100 : $x = 76{\cdot}1$, or say $= 76$ per cent.

When the temperature is below freezing-point, certain precautions have to be observed in using the wet-bulb thermometer (see certain textbooks on meteorology or physics).

VIII. Condensation, Clouds, and Precipitation.—The water vapour which is continually being evaporated from the surface of the ocean into the atmosphere by

the heat of the sun, and to a smaller extent independently of the direct rays of the sun, sooner or later returns, as we all know, in the liquid form to the sea; and it is by this continuous process of distillation and condensation that the dry land ultimately derives all its water-supply, and is thereby rendered habitable. Now, what are the conditions necessary for condensation to take place, and what are the main stages in the process? It has been demonstrated, mainly by Aitken, that, if the air were pure, condensation into clouds, mist, and rain, would not take place when the point of saturation was reached, and that the atmosphere would constantly be in a condition of what physicists call *supersaturation*, in which condition it would deposit a layer of water upon all solid objects in contact with it. But the atmosphere is not pure air and water vapour, but is charged, even at high mountain levels, with impalpable dust, composed of various substances derived from the surface of the earth; and it is the particles of this dust (together with the "ionised" particles of air) which furnish the nuclei around which the minute drops of water-vapour may condense.

The exact nature of the process of condensation is still very imperfectly understood; but in the ordinary way the first stage is the passage of aqueous vapour into cloud, fog, or mist, which, if the process is continued, passes into rain or snow.

Owing to the large quantity of latent heat which is liberated when steam or vapour is condensed to the liquid form, condensation always has the effect of checking any fall of temperature which may for other causes be taking place in the atmosphere. It is for this reason that damp countries are all over the world much warmer than, being deprived by

cloud of so much direct sun-heat, they otherwise would be.

There are various causes which may lower the temperature of the atmosphere to the condensation-point, but the primary one is the ascent of masses of air to higher levels, whereby expansion and cooling takes place (see earlier chapters).

It is one of the fundamental principles to be learned in thermo-dynamics that, when a gas expands, not through the application of heat, but through being relieved of a portion of its external pressure, it undergoes a reduction of temperature, becoming adiabatically cooled; and, conversely, when a gas contracts or is compressed, not through the application of cold, but through being subjected to increased external pressure, its temperature rises, becoming adiabatically warmed. Now it has come to be established as a leading principle in meteorology that, when the air is circulating cyclonically—that is, inwards towards a centre—it is also ascending, and when anti-cyclonically—that is, outwards from a centre—descending. This at once explains why a cyclonic action of the atmosphere usually produces clouds and rain, and an anti-cyclonic action clear skies and dry weather, excepting when surface fog or valley mists, caused by the cold of nocturnal radiation, occur. The ascending column of air in a cyclone rises to regions where the pressure is less than its own; here expansion, and, consequently, cooling and condensation, take place. The descending column of air in an anti-cyclone, on the contrary, is falling into regions of increased surrounding pressure, thereby becoming compressed, and consequently warmed, with increased capacity for moisture.' So great, however, is the quantity of moisture to be

dissipated in the reeking atmosphere over the British Islands, that anti-cyclonic weather is as often as not hopelessly cloudy; and when this is the case, the sky is often more gloomy, and far less broken and changeable, than in the stormy cyclonic conditions. In addition, to causes connected with cyclonic or anti-cyclonic movement, ascending and descending currents of air may be engendered by topographic circumstances; and we have already seen how mountains and hills provoke a very high local rainfall by forcing upwards the moisture-laden winds which blow against them. The thermo-dynamic cooling of expanding air at high levels, and warming of contracting air at low, effectively prevent respectively rising air from bringing the warmth of the lower to high levels, and falling air from bringing the cold of the upper atmosphere to the surface of the earth. The bodily upthrust of the whole atmosphere from bottom to top which must necessarily take place over the heated tropics (for the heated expanding layers of air must lift up the unheated layers above them) is no doubt the explanation of a curious fact which has been disclosed by the ascent of kites and balloons carrying self-recording instruments—namely, that over the tropics the upper air miles above the highest mountains is colder than in the colder latitudes at the surface.

IX. Cloud-Forms, Rain, Snow, and Hail.—Among the infinite variety of detached cloud-forms, three main types may be recognised: Cirrus, with a hair-like, feathery, or fibrous structure; stratus, of flat, sheet-like form; and cumulus, a compact mass, or heap of cloud, of bold, striking, and often mountainous proportions. Cirrus cloud, being formed usually at very high levels, are composed of ice or snow instead of

water particles. A cirrus sky often assumes the most beautiful and wonderful patterns. Cumulus clouds represent the visible condensed summit of a column of vapour in ascending air, and assume the most imposing forms in showery weather, more especially on sultry days in summer, when upward currents of warm, damp air are strong, giving rise to local thunderstorms. Although we have many leaden overcast days in the British Islands, our northern skies often break into sunlit cloud-scapes, which for wildness and beauty of form and colouring cannot be surpassed anywhere, and across no other land do the westerly winds carry the cumulus clouds more majestically than they do over the green face of England. When cloud particles grow with increased condensation too heavy to be supported by the atmosphere, they fall as raindrops.

The rapidity with which rain falls and the size and texture of the drops of course vary enormously. For the measurement of rain a great many patterns of gauge, self-recording or otherwise, are in use. Full particulars as to the best instruments to use can be obtained from the British Rainfall Organisation at 62, Camden Square, London, N.W.

It is a remarkable fact, which cannot be too strongly emphasised, that in London persistent rain, lasting unbroken for twelve to forty-eight, or even more hours, nearly always occurs with an east or north-east wind, and very rarely, one might almost say never, with a west or south-west wind, which brings more intermittent rain and more broken skies.

Rain is one of the most powerful agencies concerned in the denudation of the land and the weathering of rocks. In limestone districts, the solvent action of rain, owing to the carbon dioxide gas which it dissolves

out of the atmosphere, is very remarkable. Nowhere in England is this more apparent than in the Ingleborough district of Yorkshire, where the surface of the limestone has been eaten into deep fissures and swallow-holes. Many of the streams in this district have two channels—a subterranean course in comparatively dry weather, and an open-air one in flood-time. It seems almost incredible that the deep subterranean passages and chambers in the limestone should thus become completely waterlogged in wet weather; but none who know the violence and persistence of rain on the Pennine Chain—the desolate, weather-beaten backbone of England—will wonder at the result.

When vapour condenses out of the atmosphere at a temperature below freezing-point, it does so in the form of beautiful six-sided crystals of snow. The texture of snowflakes is very various, from the wet sleet, so common in Western Europe, on the one hand, to the dry, sand-like blizzard of the North American prairie on the other.

Canadian snow is said to be too dry to be fashioned into snowballs like English snow, because the temperature of the air is so far below 32° F. The percolating power of melting snow exceeds that of rain, and so snow is in rural districts considered to be more efficient in replenishing wells and springs. The southern parts of England are somewhat liable to heavy late spring snowstorms. Around April 24, 1908—that is, within two months of mid-summer—Hampshire, Berkshire, and contiguous counties in the south of England, lay buried beneath a mass of snow from 1 to 2 feet in depth, and when the summer sun shone on the landscape, the effect was magnificent, though there were

lacking those bewitching shades of rose and purple seen when a winter sun touches a snowclad landscape.

When cloud particles freeze, or when raindrops in their descent encounter a stratum or current of air below the freezing-point, they are congealed into hailstones. The structure of hail is complex, and its mode of formation somewhat obscure. Hail in its most destructive form is invariably associated with the electric manifestations of thunderstorms; but why so icy an article of atmospheric production should be characteristic of the hot weather conditions of thunderstorms, is not yet thoroughly understood.

Hail is of two main kinds: hard or true hail, which falls in summer, generally in association with thunderstorms; and soft hail (called *graupel* or *grésil*), which commonly falls with bleak northerly winds in winter, often alternating with snow.

Weather Charts.

The British Meteorological Office, situated in South Kensington, receives twice daily telegraphic information from various places in Western Europe (also "wireless" messages from ships out in the Atlantic) concerning the height of the barometer, the temperature of the air, the strength of the wind, and general state of the weather. The barometric readings, after being reduced to a standard level, taken as that of the surface of the sea, in order to render them comparable, and subjected to a further correction for temperature—being reduced to what they would be at the freezing-point of water, 32° F. (0° C.), since the

length of the mercurial column in the barometer varies with the temperature—are plotted on a chart, and lines are then drawn through all places which show the same atmospheric pressure. The lines thus drawn are called *isobars* (Gr. *isos*, equal, and *baros*, weight), and upon these isobaric charts forecasts of the probable state of the weather during the ensuing twenty-four hours are based. Little reliance can be placed upon the height of the barometer at a single station as a guide to coming weather. For forecasting purposes we require to know the simultaneous height of the barometer over a wide area, and a study of the daily pressure charts published by the Meteorological Office will soon enable anyone to understand why this is the case.

If the temperature readings are plotted on the same chart as the pressure readings, and lines drawn through them in the same way (*isothermal* lines—from *isos*, and *therme*, heat), and the general character of the weather and state of the sea are also indicated, the result is called a *synoptic* chart. All civilised nations now have a meteorological office or bureau—usually a Government department—where weather forecasts and storm-warnings are prepared.

The following five charts are selected from recent issues of the Daily Weather Report of the Meteorological Office to illustrate a few distinct types of distribution of atmospheric pressure, each associated with a different kind of weather.

The explanation of the charts, which we quote from the Daily Weather Report itself, is this:

Barometer.—Isobars are drawn for each tenth of an inch.

Wind.—Arrows, flying with the wind, show direction

and force, thus [the Beaufort scale of wind force, 0 to 12, is employed in the Reports]:

Force above 10, →→—→. Force 8 to 10, →—→.
Force 4 to 7, —→. Force 1 to 3, —⇀.
Calm, ⊙.

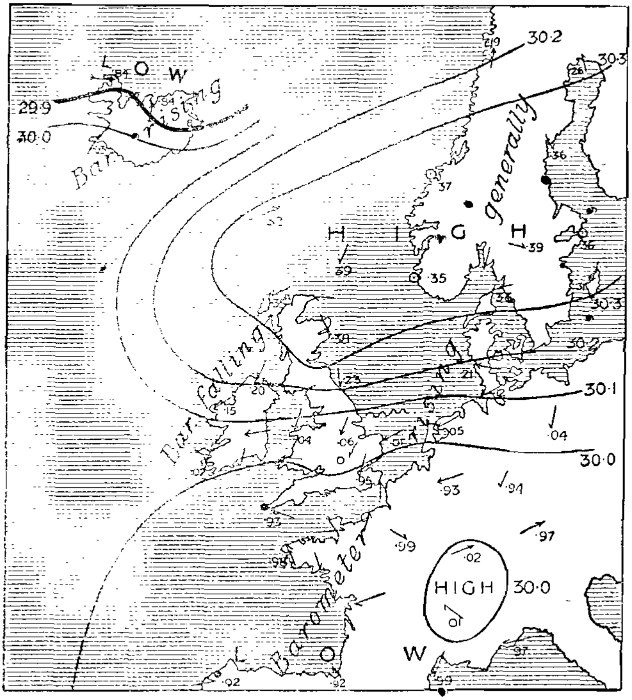
Temperature.—Given in degrees Fahrenheit. Isotherms by dotted lines.

Weather. — Shown by the following letters and symbols: b, clear sky; c, cloudy; o, overcast; ≡, fog; ●, rain falling; ▲, hail; *, snow T, thunder; Ṟ, thunderstorm.

Sea Disturbance.—Rough, ∿∿∿; high, ≋≋≋.

JUNE 7, 1910.

BAROMETER, WIND, AND SEA AT 7 A.M.



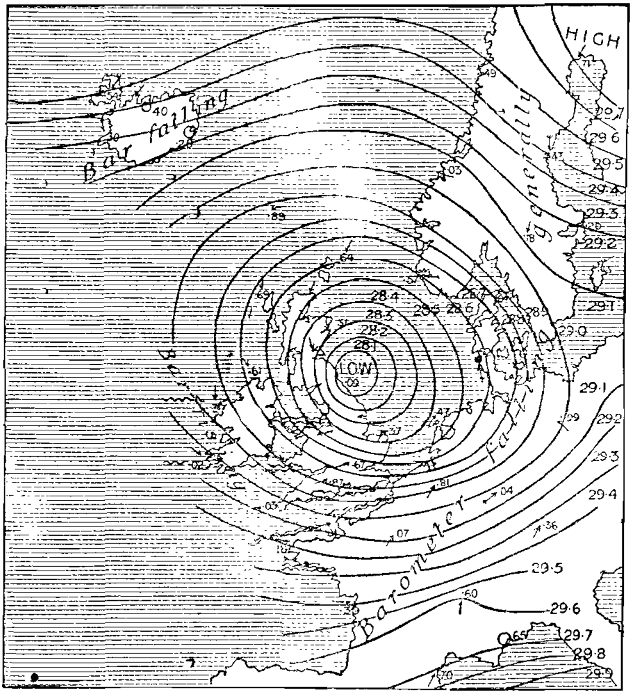
THUNDERSTORM DISTRIBUTION OF PRESSURE.

The South of England and the North of France lie in a neck of slightly lower pressure, situated between two anti-cyclones, or high-pressure systems. Local thunderstorms invariably accompany this kind of distribution of atmospheric pressure in summer, the physical reason being that the lateral pressure on either side of the neck of low pressure, due to the air flowing outwards and downwards from the anti-cyclones, tends to force upward masses of warm, moist air in this neck, resulting in rapid condensation and inductive electrification.

During the day thunderstorms of a violent type accordingly occurred at various places in the neck of relatively low pressure. The map does not indicate these local storms, but shows the very slight pressure differences and consequent calm, sultry air so characteristic of thundery weather. Electrical disturbance is most common around midsummer, May to July.

DECEMBER 3, 1909.

BAROMETER, WIND, AND SEA AT 7 A.M.



CYCLONIC STORM.

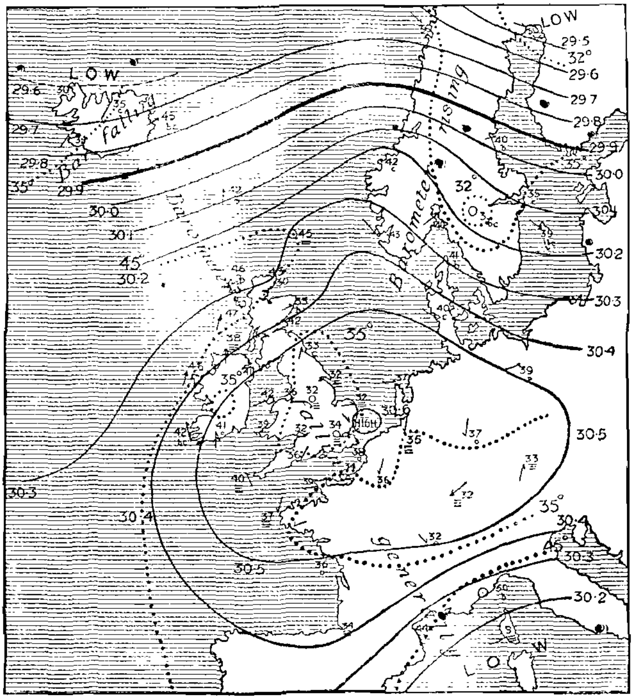
The centre of a deep and violent cyclonic storm is shown off the coast of Northumberland with the barometer below 28·1 inches. The wind is blowing very strongly in consequence of the closeness of the isobars—*i.e.*, the steepness of the barometric or pressure gradients.

All through the previous night there had raged one of those terrific and disastrous gales of wind and rain so common in the depth of winter in the British Islands. The wind, be it observed, is from the west, south of the central area, and from the east, north of it. The system, as usual, was travelling from the Atlantic, as an eddy in the general eastward air-stream which normally flows in our latitude, the barometer falling in front and rising in rear. This is why the barometer usually falls rapidly on the approach of bad weather.

JANUARY 20, 1911.

SYNOPTIC CHART FOR 7 A.M.

(*Pressure, thick lines ; temperature, dotted lines.*)

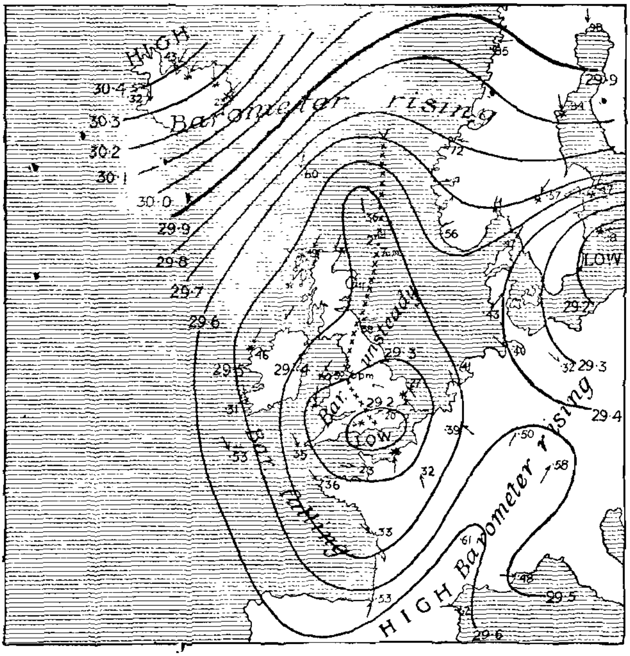


ANTI-CYCLONE.

An extensive system of high barometric pressure prevailed witl great persistence over Western Europe towards the end of January The accompanying weather was calm, rather mild in temperature, bu terribly dismal and gloomy. Sometimes, however, an anti-cyclon brings clear blue skies and brilliant sunshine, and when this occurs in summer the heat is liable to be very great. Occasionally winter anti-cyclones bring intense frost, but there was little frost while the above system prevailed

MARCH 3, 1909.

BAROMETER, WIND, AND SEA AT 7 A.M.

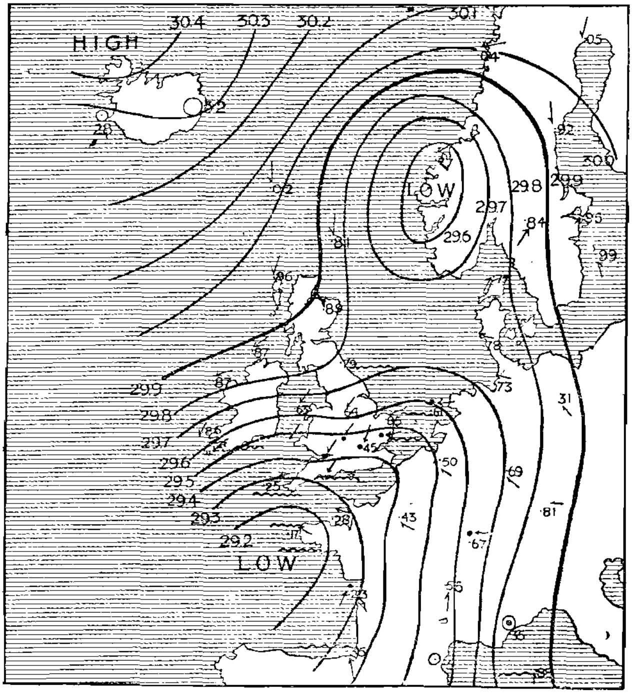


SNOWY WEATHER.

The pressure situation on this morning was favourable to weather of the genuine Arctic type. The barometer, it will be seen, was high over Iceland; and during the early days of March a series of small atmospheric depressions, like that seen on the chart over the English Channel, associated with a flow of Polar air over the United Kingdom, occasioned great quantities of snow in many parts of the country, with severe cold everywhere.

OCTOBER 27, 1909.

BAROMETER, WIND, AND SEA AT 7 A.M.



PERSISTENT EAST WIND AND RAIN.

The centre of a cyclonic system is shown over the Bay of Biscay, and another over the South of Norway. The South of England lay for three days under the influence of the northern part of the system, and hence experienced easterly winds, with much rain. In London rain fell heavily and persistently over the greater part of the 26th, 27th, and 28th. The rain was extremely cold, the weather being of an exceedingly raw and inclement, but, of course, quite seasonable, character.

BOOKS ON METEOROLOGY

The following works may be recommended to those anxious to pursue the study of the science of meteorology:

ABERCROMBY, Hon. R.: Weather: A Popular Exposition of the Nature of Weather Changes from Day to Day. 8vo. 1887. 5s.

Bartholomew's Atlas of Meteorology. Folio. 1899. 52s. 6d.

CLAYDEN, A. W.: Cloud Studies. 8vo. 1905. 12s.

Daily Weather Reports of the Meteorological Office. 4to. Annual Subscription, 21s.

Weekly Weather Reports of the Meteorological Office. 4to. Annual Subscription, 30s.

DICKSON, H. N.: Meteorology. The Elements of Weather and Climate. 8vo. 1893. 2s. 6d.

FERREL, W.: A Popular Treatise on the Winds. 8vo. 1889. 16s.

HANN, J.: Handbook of Climatology. Translated from the German by R. de C. Ward. 8vo. 1903. 12s. 6d. Second revised and enlarged edition not yet translated.

HANN, J.: Lehrbuch der Meteorologie. 8vo. Second edition. 1905. 24s.

MARRIOTT, W.: Some Facts about the Weather. 6d. Second edition. 1909.

MILL, H. R.: British Rainfall. 8vo. Published annually. 10s.

MOORE, Sir J. W.: Meteorology: Practical and Applied. 8vo. 6s. Second edition. 1910.

Symons's Meteorological Magazine. Edited by Dr. H. R. Mill. 8vo. Published monthly. 4d.

APPENDIX

If P be the initial pressure, P_1 the final pressure, V the initial volume, and V_1 the final volume, Boyle's Law may be expressed by the equation:

$$V : V_1 :: P_1 : P, \text{ or } \frac{V}{V_1} = \frac{P_1}{P};$$

and if C be the initial temperature, and C_1 the final temperature, Charles's law may be expressed by the equation:

$$V : V_1 :: C : C_1, \text{ or } \frac{V}{V_1} = \frac{C}{C_1}.$$

The two laws may then be connected by the equation:

$$V : V_1 :: CP_1 : C_1P, \text{ or } \frac{V}{V_1} = \frac{CP_1}{C_1P}.$$

The changes of pressure which take place in the free atmosphere are, so far as is known, due almost entirely to variations in the density of the air, and not in its temperature. In other words, when a portion of the atmosphere is locally heated or cooled, the surrounding atmosphere does not act like the rigid walls of a steam-boiler, causing the steam-pressure to vary with the temperature; but it permits the air when heated to expand against the external pressure, and when cooled to contract in consequence of the external pressure, exerted in each case by the surrounding atmosphere itself.

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